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THE QUEENSLAND JOURNAL OF AGRICULTURAL SCIENCE

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OCCURRENCE AND CORRECTION OF COPPER DEFICIENCY OF SHEEP IN NORTH-WESTERN QUEENSLAND

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SUMMARY.

The occurrence and correction of copper deficiency in Merino sheep on an affected property in north-western Queensland were studied in three trials in successive years. The effects of copper supplementation on growth of weaner sheep, wool production, wool quality and reproductive performance were examined.

Pasture analyses showed that copper deficiency in sheep was due partly to the low copper and partly to the high molybdenum and inorganic sulphate levels in the predominant vegetation. Some herbage plants, which were abundant in autumn and winter after heavy summer rain, showed particularly high concentrations of molybdenum and inorganic sulphate.

The experimental sheep were 450 weaners approximately 10 months of age at the commencement of the 1953-54 trial. Different groups received 20 and 30 mg. Cu respectively as copper glycinate by subcutaneous injection at 6-monthly intervals, 200 mg. Cu as a copper sulphate drench at 6-monthly intervals, and 200 mg. Cu as a copper sulphate drench at monthly intervals.

Liver copper concentrations were unexpectedly high (mean 160 p.p.m. Cu) at the commencement of the trial. In the controls these levels decreased gradually but were low only during the last few months of this trial. Treatments at 6-monthly intervals maintained fairly satisfactory reserves. Depletion was greatest during autumn-winter, when herbage plants were abundant. Monthly treatments built up and maintained good liver copper reserves. In this trial copper treatments had no influence on body weight or wool growth.

During 1954-55 the experimental sheep were re-distributed into three groups—an untreated control, a group receiving 30 mg. Cu as copper glycinate subcutaneously (in September and December) and a group receiving 280 mg. Cu as copper sulphate drench (in September and December).

Ewes in each group were mated. Copper treatments had no influence on reproductive performance, birth weight, neo-natal mortality or growth rate to marking. All lambs had low liver copper reserves at 3–4 months of age irrespective of the copper status in their dams.

Only the ewes from the drenched group, which consisted predominantly of sheep from the group drenched once a month in the previous trial and thus had good liver copper reserves, showed a marked response in wool production. These ewes produced about 0.5 lb. per head more greasy wool. There was a significantly higher incidence of copper deficiency lesions in fleeces from the untreated control group.

During 1955-56 the lambs born to ewes during the 1954-55 trial were divided into an untreated control group and a group drenched with copper sulphate on two occasions at a month's interval (140 mg. Cu in September, 210 mg. Cu in October) and on a third occasion after five months (280 mg. Cu in March). Copper supplementation did not influence weight gains or wool production, but there was a high incidence of copper deficiency lesions in fleeces from the untreated group.

From these studies recommended treatments to prevent copper deficiency in sheep in this locality are (a) establish a good initial liver copper concentration by three treatments at fortnightly or monthly intervals and then maintain these reserves by 3-monthly treatments; and (b) treat lambs at marking and thereafter at about 3-monthly intervals.

I. INTRODUCTION.

Copper deficiency affecting sheep in Queensland was reported by Lee and Moule (1947), who recognised typical lesions in the wool of sheep that had low concentrations of copper in their blood and liver. Affected animals were located in the Cloncurry, Richmond and Hughenden districts in north-western Queensland.

Harvey (1952) defined three localities in Queensland that account for at least 90 per cent. of the affected wool produced in the State. In each of these localities confirmation was obtained by copper determinations on blood and/or liver. One is a large area around Cloncurry and extending east to Hughenden; the second is the south-easterly portion of the Darling Downs; and the third is a small area from Roma to Muckadilla.

A property situated in the Hughenden–Cloncurry area was selected for studies on copper supplementation of sheep. This property was chosen because it is within the most extensive of the affected areas, it had shown a high incidence of affected fleeces for several years irrespective of season, and it was considered that the smaller size and lower reproductive rate of sheep in this area might be due in part to copper deficiency.

In north-western Queensland, sheep are kept under extensive pastoral conditions (about one sheep to six acres), so topdressing of pastures would be a major undertaking. As shown by Harvey (1952), soils in this area are usually rich in copper, but this copper is not readily available to the predominant pasture plants. Thus only a limited response would be expected from topdressing. As internal parasites seldom affect sheep in this area, drenching with medicaments containing copper is rarely practised. Feed supplements or salt licks containing copper are expensive, difficult to distribute and not eaten readily by all sheep. Copper supplementation through drinking water cannot always be arranged conveniently. It is dependent on the carefully controlled treatment of the drinking water in concrete or proofed iron troughs; on many properties stock drink directly from bore drains, and on others the underground water contains salts that precipitate copper.

The investigations described here extended over three years and embraced the occurrence and correction of copper deficiency in sheep, with particular reference to the effect of copper supplementation on the growth of young sheep; the quality and quantity of wool produced; and the reproduction of adult sheep. Copper supplementation by oral administration of copper sulphate and by subcutaneous injection of copper glycinate (copper aminoacetate) was studied. The work was done in three field trials, which are reported separately.

II. MATERIALS AND METHODS.

(1) Experimental Paddock.

This covers approximately 4,000 acres of rather open undulating downs. The western portion (area A) is of brown soil and the pasture is predominantly *Astrebla* spp. (Mitchell grasses). The eastern portion (area C) is of grey soil and carries a considerable proportion of *Iseilema* spp. (Flinders grasses) as well as Mitchell grasses. A number of stony ridges (area B) lightly timbered with *Acacia cana* (boree) separate these two areas. In certain seasons there are wide varieties of herbage plants (forbs or non-gramineous plants), which predominate on the stony ridges. The locality is one of essentially summer rainfall, which results in an abundance of herbage plants from February to June in most years.

A flowing artesian bore supplies the drinking water, which is reticulated through an extensive bore-drain system.

This experimental paddock was used throughout Trials 1, 2 and 3. Experimental sheep were transferred to small holding paddocks for approximately three days each time body weights were recorded. In Trial 2, ewes were held in a small paddock from Feb. 16 to Mar. 29, 1955 while lambing observations were made.

(2) Soil.

Samples of soil from the experimental paddock were collected with a steel spade. The roots of pasture plants in this area are in the top 6 in., so soil samples were taken to a depth of 6 in. only. Samples were taken from area A and area C of the paddock. Both are clay soils of heavy texture. The stony ridges (area B) were not sampled.

(3) Pasture.

Samples were collected by hand, using stainless steel scissors, care being taken to avoid contamination. At each sampling an attempt was made to collect samples of each plant species that appeared to be abundant and eaten by sheep. All samples were identified by the Government Botanist prior to chemical analysis.

(4) Experimental Sheep.

These comprised 450 Merino weaners 8–10 months of age at the commencement of Trial 1. They were flock sheep born on a neighbouring property and brought to the experimental property for shearing one month before the trial began.

All animals were treated with the Mules operation and vaccinated against blackleg, tetanus and *Clostridium septicum* to minimise losses during the course of the experiment. Liver biopsies were made by the technique of Dick (1944, 1950). Samples were partially dried in an oven on the property before being air-freighted to the laboratory.

(5) Chemical Methods.

Copper was determined in soil, pasture, liver and blood by the method of Clare, Cunningham and Perrin (1945). Molybdenum was determined by the method of Dick and Bingley (1951). Inorganic sulphate was determined by a modification of the benzidene sulphate method of J. B. Bingley and A. T. Dick (personal communication 1953).

(6) Copper Treatments.

Copper was given orally as a 4 per cent. solution of copper sulphate in distilled water, using an automatic drenching gun.

Copper was injected subcutaneously with an automatic syringe as an aqueous solution of copper glycinate containing 2·5 mg. copper (Cu) per ml. The solution was injected in the inner aspect of the left thigh, a wool-free site; this permitted subsequent observation of any lesions produced.

On each occasion, copper treatments were not undertaken until the collection of all samples for chemical analysis had been completed.

(7) Body Weight.

Body weight of all experimental sheep was measured with a clock-face spring balance. On each occasion, animals were yarded for approximately the same time prior to weighing. All animals were weighed before the liver biopsy and treatment.

(8) Wool.

All sheep were shorn prior to the commencement of Trial 1 and subsequently at intervals of approximately 12 months. Greasy fleece weight was recorded for each experimental sheep, and wool samples from each

animal were sent to the laboratory for determination of clean fleece weight, fibre diameter, staple length, number of crimps per in., and the presence of lesions attributable to copper deficiency.

(9) Lambing.

Lambing observations were made in Trial 2, using the procedure described by Moule (1954). All experimental ewes were transferred to a small paddock on Feb. 16, 1955 and lambed under surveillance. Data recorded were number of ewes lambed and lambs born, birthweight of lambs, number of deaths and weight gain to marking. On Mar. 29, 1955, all surviving ewes and lambs were returned to the experimental paddock.

III. TRIAL 1 (1953-54).

(1) Experimental.

The 450 experimental weaners were distributed at random into five groups of 90 sheep. The procedure was to run all sheep through a race. Distinguishing raddle marks were applied so that a sheep from the first five in the race was allotted to one of the five groups. This was repeated for each successive five sheep in the race. Sheep were individually identified with numbered ear-tags. As each group was weighed, every third sheep was drafted into a sub-group of 30 for liver biopsy. The aim was to obtain liver samples from 25 sheep in each group.

The groups were allotted at random to the treatments as follows:

Group 1. Untreated control.

Group 2. 20 mg. Cu as copper glycinate given subcutaneously at 6-monthly intervals (September 1953 and March 1954).

Group 3. 30 mg. Cu as copper glycinate given subcutaneously at 6-monthly intervals (September 1953 and March 1954).

Group 4. 200 mg. Cu as copper sulphate given orally at 6-monthly intervals (September 1953 and March 1954).

Group 5. 200 mg. Cu as copper sulphate given orally once a month from September 1953 to June 1954 inclusive.

The trial commenced in September 1953 and finished in September 1954. All sheep were weighed in September and thereafter at 3-monthly intervals. Liver biopsy samples were taken every three months from approximately the same 25 sheep in each group.

The sheep were shorn in July 1953 and again in June 1954, approximately nine months after the commencement of the trial.

Pasture samples for chemical analysis were taken from the experimental paddock in September 1953 and thereafter at 3-monthly intervals. Soil samples from this paddock were taken in September 1953 and September 1954.

(2) Results.

The 1953-54 season was particularly favourable for pasture growth, with unusually heavy rain for this locality in February and March (Table 1). This resulted in abundance of herbage plants from February to June. Fig. 1 shows the ample pasture available to sheep in the experimental paddock in March 1954.

Fig. 1.

Photograph Showing the Abundance of Grass and Other Herbage Plants in the Experimental Paddock in March 1954.

Table 1.

RAINFALL RECORDED ON EXPERIMENTAL PROPERTY (INCHES).

Month.	1952.	1953.	1954.	1955.	1956.
January	1·34	4·79	4·66	7·36	5·92
February	·09	12·03	12·25	11·61	5·57
March	·31	·00	11·93	4·46	1·73
April	·10	·00	1·63	2·14	3·58
May	·30	·00	·00	6·41	1·48
June	·00	·00	·45	·41	1·15
July	·00	·00	·00	·00	·66
August	·00	·89	·00	·00	·00
September	·44	·00	·00	·00	·00
October	·17	·00	1·54	·00	·15
November	·71	·14	2·12	·28	·65
December	2·09	·92	1·80	1·97	7·37
Total	5·57	18·77	36·38	34·64	28·26

Sept. 1952—Birth of experimental sheep.
July 1953—Pre-experimental shearing.
Sept. 1953—Commencement of Trial 1.
Sept. 1954—End of Trial 1 and commencement of Trial 2.
Sept./Oct. 1954—Ewes mated.
Feb./Mar. 1955—Lambing observations.
June 1955—End of Trial 2 and commencement of Trial 3.
June 1956—End of Trial 3.

Chemical analyses of soils are shown in Table 2. The brown soil from area A is alkaline; it has a high level of total copper and molybdenum, and is low in nitrogen and rich in available phosphate. The grey soil from area C

Table 2.

PARTIAL CHEMICAL ANALYSIS OF THE TWO MAJOR SOIL TYPES IN EXPERIMENTAL PADDOCK.
(Expressed on dry-matter basis.)

Location.	Date Sampled.	Copper (p.p.m. Cu).	Molybdenum (p.p.m. Mo).	pH.	Nitrogen (%)	Available Phosphate (p.p.m. P_2O_5).
Area A* ..	September, 1953	75	..	8·0	0·07	580
Area A ..	September, 1954	78	31	..	..	..
Area C† ..	September, 1953	32	..	7·4	0·04	400
Area C ..	September, 1954	32	7	..	..	..

* Brown clay soil of heavy texture.
† Grey clay soil of heavy texture.

is only slightly alkaline; the total copper and molybdenum levels are appreciable but lower than in area A; the nitrogen content is low and the available phosphate content is high.

PARTIAL CHEMICAL ANALYSIS OF THE PREDOMINANT VEGETATION IN EACH SECTION OF THE EXPERIMENTAL PADDOCK.

Area.	Plant.	Sept., 1953.	Dec., 1953.	March, 1954.		June, 1954.			Sept., 1954.			June, 1955.		
		Cu.	Cu.	Cu.	Mo.	Cu.	Mo.	SO_4.	Cu.	Mo.	SO_4.	Cu.	Mo.	SO_4.
		p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	%	p.p.m.	p.p.m.	%	p.p.m.	p.p.m.	%
A	*Astrebla* sp.	3·9	1·8	2·1	6·2	3·4	3·2	0·7	1·7	11·6	0·7	2·8	7·2	0·4
	Iseilema sp.	..	..	..	..	..	..	..	..	..	..	3·4	8·7	0·5
	Eriochloa sp.	..	..	..	..	4·3	7·7	1·7	..	..	..	..	..	..
	Digitaria ctenatha	..	..	3·3	2·6	..	..	..	..	..	..	..	..	..
	Sesbania aculeata	..	..	7·5	8·0	..	..	..	..	..	..	10·2	34·2	1·0
	Cucumis tregonis	..	..	9·0	3·5	8·2	2·0	0·5	..	..	..	..	..	..
	Citrullus colocynthis	..	..	8·1	4·8	..	..	..	..	..	..	..	..	..
	Operculina turpethum	..	..	6·1	4·6	..	..	..	..	..	..	..	..	..
	Flaveria australasica	..	..	6·1	19·0	..	..	..	..	..	..	..	..	..
	Ipomoea turpethum	..	..	..	..	8·5	2·1	0·01	..	..	..	..	..	..
	Pterigeron adscendens	..	..	..	..	..	..	..	5·8	15·1	1·7	..	..	..
	Hibiscus ficulneus	..	..	5·9	6·4	..	..	..	..	..	..	..	..	..
	Glycine tomentosa	..	..	..	..	..	..	..	..	..	..	7·9	30·0	0·4
	Rhynchosia minima	..	..	..	..	..	..	..	..	..	..	4·1	18·2	0·3
B	*Astrebla* sp.	..	..	..	..	..	..	..	..	..	..	3·2	6·2	0·4
	Iseilema sp.	..	..	2·4	2·9	3·8	3·6	0·2	3·3	4·4	0·5	2·7	2·5	0·6
	Chloris sp.	..	..	4·5	10·0	3·9	2·0	0·05	..	..	..	..	..	..
	Dactyloctenium radulans	..	..	3·9	3·5	..	..	..	..	..	..	..	..	..
	Acacia farnesiana (pods)	..	4·3	..	..	..	..	..	..	..	..	..	..	..
	Acacia farnesiana (leaves)	..	..	..	..	5·3	1·9	0·01	..	..	..	..	..	..
C	*Astrebla* sp.	..	..	..	..	3·3	3·9	0·5	1·7	3·5	0·5	3·2	2·3	0·2
	Iseilema sp.	6·0	..	1·7	2·2	3·3	4·2	0·4	2·3	4·5	0·3	4·5	1·9	0·2
	Boerhavia diffusa	..	..	3·9	2·9	..	..	..	..	..	..	..	..	..
	Sida acuta	..	..	..	..	..	..	..	..	..	..	5·8	2·9	0·4
	Sida fibulifera	..	..	..	..	..	..	..	..	..	..	15·2	3·4	..
	Morgania glabra	..	..	..	..	..	..	..	..	..	..	10·2	5·5	0·9

Concentrations of Cu, Mo and inorganic sulphate are expressed on a dry-matter basis.

The brown soil (area A) carried predominantly Mitchell grasses; a great variety of herbage was present at the March and June 1954 samplings. The stony ridge (area B) carried little pasture in September and December 1953; there was a considerable amount of *Acacia farnesiana* (prickly bush), the pods of which were eaten avidly in December 1953 and the leaves more particularly in June 1954; Flinders grasses, *Chloris* sp. (a star grass) and *Dactyloctenium radulans* (button grass) were present in March 1954, with Flinders grasses predominating. The grey soil (area C) carried mainly Flinders and Mitchell grasses, with some herbage plants in autumn-winter.

Copper, molybdenum and inorganic sulphate levels in the predominant vegetation in each section of the experimental paddock are shown in Table 3. The copper content was particularly low in the grasses (2–4 p.p.m. Cu D.M.), whereas the herbage plants contained 6–15 p.p.m. Cu D.M. The molybdenum levels were appreciable, being particularly high in some herbage plants from area A. Most plants showed a high concentration of inorganic sulphate.

The mean concentrations of copper in the livers of animals from each group, taken at 3-monthly intervals, are shown in Table 4.

Table 4.

MEAN COPPER CONCENTRATION IN LIVERS OF SHEEP IN TRIAL 1.
(Cu p.p.m. dry-matter.)

Group.	Sept., 1953.	Dec., 1953.	March, 1954.	June, 1954.	Sept., 1954.
1 ..	156 (8)*	115 (29)	63 (60)	21 (100)	22 (100)
2 ..	158 (4)†	266 (0)	123 (20)†	99 (28)	55 (74)
3 ..	172 (12)†	301 (0)	142 (20)†	133 (24)	77 (70)
4 ..	151 (8)†	205 (0)	118 (41)†	112 (11)	49 (77)
5 ..	164 (8)†††	345 (0)†††	315 (0)†††	275 (0)†	238 (8)

* Figures in brackets show percentage of sheep with liver copper concentrations less than 80 p.p.m.
† Indicates treatment with copper, immediately after this liver biopsy.
††† Indicates three treatments with copper at monthly intervals.

The liver copper reserves were unexpectedly high at the commencement of the trial, the mean being 166 p.p.m. Cu, with 8 per cent. of the sheep showing less than 80 p.p.m. Cu and 24 per cent. showing more than 200 p.p.m. Cu.

The untreated Group 1 showed a progressive fall in liver copper concentration. In March 1954, six months after the commencement of the trial, the mean level was 63 p.p.m. Cu, with 60 per cent. of the sheep showing less than 80 p.p.m. Cu. In June 1954, the mean level was 21 p.p.m. Cu and all animals had less than 80 p.p.m. Cu. This low level was maintained in September 1954.

Group 2, which received 20 mg. Cu subcutaneously in September 1953 and March 1954, showed a marked increase in liver copper concentration in December 1953. In March 1954 the liver copper status was below that recorded at the initial sampling six months previously. In June 1954, the liver copper levels were lower than those found in March in spite of re-treatment after the March biopsy. There was a further depletion by September.

Group 3, which received 30 mg. Cu subcutaneously in September 1953 and March 1954, showed changes in liver copper storage similar to Group 2, although the reserves were greater due to the higher dose rate.

Group 4, which received 200 mg. Cu orally in September 1953 and March 1954, showed liver copper levels comparable with those of Group 2.

Group 5, which received 200 mg. Cu orally at monthly intervals, was the only group that maintained adequate liver copper reserves throughout the 12 months.

During this trial 10 sheep were accidentally killed during liver biopsy. The opportunity was thus presented to compare analyses on liver biopsy samples with analyses on larger representative samples taken from these livers at autopsy. For liver copper concentrations ranging from 10 to 400 p.p.m., the experimental error on the biopsy sample was about ± 11 per cent. of the true value.

The mean body weights for ewes and wethers in each group, recorded at 3-monthly intervals, are presented in Table 5. There were no differences between groups.

Table 5.

MEAN BODY WEIGHTS OF SHEEP IN TRIAL 1.

Group.	Type.	Sept., 1953.	Dec., 1953.	Mar., 1954.	June, 1954.	Sept., 1954.
		lb.	lb.	lb.	lb.	lb.
1	Ewes ..	48·8	52·9	64·5	75·8	80·3
2	Ewes ..	47·1	49·6	63·5	74·7	79·0
3	Ewes ..	43·6	49·5	61·7	73·0	78·1
4	Ewes ..	43·8	50·0	63·1	75·4	79·4
5	Ewes ..	47·6	54·3	65·7	78·2	81·7
1	Wethers ..	52·8	57·9	70·5	83·0	89·4
2	Wethers ..	51·8	54·8	69·9	81·5	88·6
3	Wethers ..	49·2	55·7	68·5	81·3	87·2
4	Wethers ..	45·6	51·9	67·0	81·3	87·2
5	Wethers ..	50·6	55·9	68·9	83·1	91·1

The mean greasy and clean-scoured fleece weights for ewes and wethers in each group are shown in Table 6. There were no significant differences between groups in greasy or clean wool production or in wool quality.

Table 6.

MEAN GREASY AND CLEAN SCOURED FLEECE WEIGHTS OF SHEEP IN TRIAL 1.

Group.	Type.	Mean Greasy Fleece Weight.	Mean Clean Scoured Fleece Weight.
		lb.	lb.
1	Ewes	6·09	3·37
2	Ewes	6·09	3·40
3	Ewes	5·94	3·25
4	Ewes	6·01	3·21
5	Ewes	6·25	3·47
1	Wethers	6·68	3·77
2	Wethers	6·75	3·66
3	Wethers	6·22	3·41
4	Wethers	6·22	3·39
5	Wethers	6·52	3·52

At the conclusion of the trial in September 1954, the body weights of sheep that had been biopsied on four occasions were compared with those of un-biopsied sheep. There were no significant differences, indicating that repeated liver biopsy had no effect on weight gain.

(3) Discussion.

The level of copper is particularly low in the grasses in spite of adequate total copper in soils. This is evident even in area A, where the total copper in soil is high. It would appear that copper in soils in this locality is largely unavailable to the predominant pasture species. As might be expected in alkaline soils, the availability of molybdenum to pasture is high. This is evident particularly in area A, where the molybdenum concentration in soil is high.

From pasture analyses it appears that copper deficiency in sheep in this locality is due partly to the low copper content of the grasses and partly to inhibition of copper metabolism in sheep by molybdenum in the presence of inorganic sulphate as shown by Dick (1952, 1953, 1954). Some herbage species contain up to 34 p.p.m. Mo, which is comparable with levels recorded in the teart pastures of Somerset (Ferguson, Lewis and Watson 1938, 1940). As the molybdenum levels are particularly high in herbage plants, it might be expected that interferences with copper metabolism would be most marked from March to June, when these plants are present in abundance and readily eaten by sheep.

The data on liver copper concentrations support the conclusion that the period of greatest depletion of copper reserves in the animals was from March to June, when herbage plants were abundant. Six-monthly treatment, either orally or subcutaneously at the dose rates used, did not maintain adequate liver copper concentrations. Group 3, receiving 30 mg. Cu as copper glycinate subcutaneously, maintained liver copper reserves slightly better than Group 4, receiving 200 mg. Cu as copper sulphate orally at 6-monthly intervals. The findings of Sutherland, Moule and Harvey (1955) indicate that 30 mg. Cu as copper glycinate subcutaneously and 200 mg. Cu as copper sulphate orally are about the maximum safe doses for sheep of this age.

The unexpectedly high liver copper reserves in sheep at the commencement of the trial may be related to the previous history of the animals. They were born on a neighbouring property during the 1952-53 drought and were brought to the experimental property only in July 1953. In the untreated group it was not until March 1954 that a majority of sheep showed levels in liver below 80 p.p.m. Cu. It was only in June 1954 that all sheep examined in this group showed a low copper status. This was reflected in the absence of lesions of copper deficiency in fleeces examined at shearing in June 1954. On the basis of liver copper reserves, lesions could be expected only in that portion of the wool fibre grown, at most, three months prior to shearing. The same reason could be advanced to explain the absence of significant differences between groups in growth rate or wool production.

IV. TRIAL 2 (1954-55).

(1) Experimental.

This trial was designed to study the effect of oral or subcutaneous copper therapy, firstly on body weight and wool production of the wether portion of the flock and secondly on breeding ewes in terms of body weight, wool production, lamb production and weight of lambs at birth, at marking and at weaning.

The experimental sheep from Trial 1 were re-allocated to three new groups as follows:

Group A. Untreated control (comprising all sheep from Group 1 plus a selection from Groups 2, 3 and 4).

Group B. 30 mg. Cu as copper glycinate given subcutaneously in September and December (comprising a selection from Groups 2, 3 and 4).

Group C. 280 mg. Cu as copper sulphate given orally in September and December (comprising all sheep from Group 5 plus a selection from Groups 2, 3 and 4).

The method of re-allocation of sheep from Trial 1 was based on four considerations:

(i) To keep all the previously untreated sheep (Group 1) in Group A. These were known to have low liver copper reserves in June 1954.

(ii) To keep all the sheep previously treated once a month (Group 5) in Group C. These were known to have good liver copper reserves in June 1954.

(iii) To allot sheep from Groups 2, 3 and 4 to the new Groups A, B and C to give approximately equal numbers of ewes and wethers, and at the same time to ensure that Groups A, B and C each contained a minimum of 20 ewes and 20 wethers whose liver copper concentrations were known from the June 1954 biopsy.

(iv) To allot sheep from Groups 2, 3 and 4 to Groups A, B and C on their body weights.

Group A contained 56 ewes and 69 wethers; Group B 57 ewes and 71 wethers; and Group C 57 ewes and 71 wethers.

Liver biopsy samples were taken from approximately 20 ewes and 20 wethers in each group at the commencement of the trial in September 1954 and at the conclusion of the trial in June 1955.

Groups B and C were injected or drenched in September and December, but the treatment planned for March had to be abandoned because of difficulties imposed by weather conditions.

All sheep were weighed in September 1954 and June 1955.

Ewes were joined with rams for six weeks from Sept. 20, 1954. The ewes lambed under close observation between Feb. 16 and Mar. 29, 1955.

All sheep were crutched in December 1954 and jetted with aldrin in March 1955.

This trial concluded in June 1955, when individual fleece weights were determined and wool samples were taken for laboratory examination.

(2) Results.

The 1954-55 season was again particularly favourable for pasture growth from November to June, with much more than the average rainfall for this locality (Table 1). As in the 1953-54 trial, there was an abundance of grass and a variety of green herbage from February to June.

The chemical analyses of pasture from the experimental paddock at the commencement of the trial in September 1954 and at the conclusion in June 1955 are shown in Table 3. The copper, molybdenum and inorganic sulphate contents of the predominant vegetation were similar to those found at the comparable periods in 1953 and 1954.

Table 7 records the mean copper concentrations in livers of sheep. The method of re-grouping of sheep from Trial 1 resulted in the mean liver copper concentration of both ewes and wethers at the commencement of the trial (September 1954) being low in Group A, moderately low in Group B, and fairly satisfactory in Group C. Samples taken in June 1955 showed a further fall in liver copper reserves in the untreated Group A, an improvement in the copper status of the injected Group B, and a fall in the liver copper levels in the drenched Group C. In June 1955, liver biopsies were made on a random selection of 9 lambs from Group A ewes, 9 lambs from Group B ewes and 7 lambs from Group C ewes. All these lambs showed a low copper status.

Table 7.

MEAN COPPER CONCENTRATIONS IN LIVERS OF SHEEP IN TRIAL 2.
(Cu p.p.m. dry-matter.)

Group.	Type.	Sept., 1954.	June, 1955.
A	Wethers	34 (100)*	16 (100)
	Ewes	29 (94)	15 (100)
	Lambs		11 (100)
H	Wethers††	60 (70)	128 (53)
	Ewes††	69 (67)	109 (31)
	Lambs		16 (100)
C	Wethers††	187 (40)	120 (47)
	Ewes††	183 (22)	113 (53)
	Lambs		25 (100)

* Figures in brackets show percentage of sheep with liver copper concentrations less than 80 p.p.m.
†† Indicates treatment with copper in September and December.

In June 1954 blood analyses were made on a random selection of 9 ewes from Group A, 8 ewes from Group B and 6 ewes from Group C. The mean results were:

Group.	Blood Molybdenum. (μg.Mo/100 ml.)	Blood Copper. (mg. Cu/100 ml.)	Liver Copper. (p.p.m. D.M.)
A—ewes	4	0·05	13
B—ewes	4	0·10	95
C—ewes	5	0·09	120

In ewes from Group A the copper concentration is low in both liver and blood. In ewes from Groups B and C treatments have resulted in fair liver copper reserves and blood copper levels lie within the normal range. The data or pasture (Table 3) indicate that these blood molybdenum levels are attributable to the very high sulphate intake limiting blood molybdenum in spite of high molybdenum intake. This was shown by Dick (1954) in pen-fed sheep.

The breeding performance of the ewes and the weights of lambs at birth and at marking are shown in Table 8. There were no significant differences between groups in numbers of lambs born, birth weight, survival to marking or daily weight gains of lambs. Daily inspections during the lambing period (Feb. 16 to Mar. 29) revealed symptoms of ataxia in one lamb from Group A.

Table 8.

Numbers and Mean Body Weights at Birth and Marking of Lambs from Ewes in Trial 2.

——	Group A.	Group B.	Group C.	Total or Mean.
Number of ewes mated	71	69	69	209
Number of ewes lambed	53	54	52	159
Number of lambs born	53	54	52	159
Number of lambs died in neo-natal period ..	9	7	4	20
Number of lambs died neo-natal to marking ..	9	16	18	42
Lambs marked—Number	35	31	30	96
Per cent.	49	45	43	46
Mean birth weight of lambs (lb.)	5·74	5·83	5·84	5·80
Mean birth weight of lambs died in neo-natal period (lb.)	4·57	4·33	6·37	4·88
Mean birth weight of lambs marked (lb.) ..	6·14	6·20	6·23	6·19
Mean daily gain of lambs that survived to marking (lb.)	0·373	0·361	0·369	0·368

Mean body weights of ewes and wethers in each group and the number of sheep used to calculate each mean are shown in Table 9. The ewes in each group were considered in three classes—ewes that did not lamb; ewes that

Table 9.

NUMBERS AND MEAN BODY WEIGHTS (LB.) AND MEAN GAINS (LB.) OF WETHERS AND DIFFERENT CATEGORIES OF EWES IN TRIAL 2.

—	Wethers.	Ewes.		
		Did not lamb.	Lambed, lost lamb.*	Lambed, reared lamb.**
Group A—				
Number	49	16	16	31
Weight—				
Sept. 1954	90	84	78	79
June 1955***	102	92	82	72
Gain	+11·8	+7·8	+3·5	−6·6
Group B—				
Number	47	11	12	33
Weight—				
Sept. 1954	87	73	77	79
June 1955***	98	80	80	72
Gain	+10·5	+7·3	+3·5	−6·6
Group C—				
Number	55	14	15	27
Weight—				
Sept. 1954	90	81	80	82
June 1955***	103	85	84	79
Gain	+12·6	+4·1	+4·3	−3·1

* Lamb died before marking age.
** Lamb present at shearing.
*** Immediately after shearing.

produced a lamb that died before marking; and ewes that had lambs present at shearing. There were no significant differences between groups. Within each group the influence of lambing performance on the body weight of ewes was highly significant ($P < 0{\cdot}001$).

Body weights of lambs after shearing in June 1955 were adjusted to a standard age of 116 days (Table 10). The mean weight gain for all groups was 0·27 lb. per lamb per day, and there were no significant differences between groups before or after adjustment.

Table 10.

LAMBS BORN TO EWES IN TRIAL 2.
NUMBERS AND MEAN BODY WEIGHT, IMMEDIATELY AFTER SHEARING IN JUNE, 1955.

Group.	Type.	Number of Lambs.	Mean Body Weight (lb.).	
			Unadjusted.	Adjusted.*
A	Ewes	19	36·3	35·9
B	Ewes	18	34·4	34·3
C	Ewes	17	32·8	32·7
A	Wethers	12	35·3	34·9
B	Wethers	13	33·9	35·0
C	Wethers	11	36·1	36·5

* Adjusted to a standard age of 116 days.

The mean greasy and clean fleece weights are shown in Table 11. There were no differences in wool production of wethers from each group but ewes from Group C produced significantly more greasy wool than ewes from Groups B and A. The level of significance ($P < 0{\cdot}05$) was obtained after adjustment for lambing performances. Ewes were considered in the same

Table 11.

NUMBERS AND MEAN GREASY AND CLEAN FLEECE WEIGHTS (LB.) OF WETHERS AND DIFFERENT CATEGORIES OF EWES IN TRIAL 2.

—	Wethers.	Ewes.		
		Did not lamb.	Lambed, lost lamb.	Lambed, reared lamb.
Group A—				
Number	48	16	16	32
Weight greasy fleece	10·16	8·76	8·56	7·88
Weight clean fleece	6·30	5·10	5·17	4·58
Group B—				
Number	47	12	11	34
Weight greasy fleece	10·25	8·81	8·69	8·00
Weight clean fleece	6·23	5·20	5·17	4·75
Group C—				
Number	54	15	15	29
Weight greasy fleece	10·30	9·25	8·88	8·59
Weight clean fleece	6·17	5·80	5·41	4·97

categories as for body weight—ewes that did not lamb, ewes that lambed but lost the lamb before marking, and ewes that had lambs present at shearing. The differences in fleece weight among ewes due to lambing performance were highly significant ($P < 0{\cdot}001$).

Table 12.

NUMBERS AND MEAN GREASY AND CLEAN FLEECE WEIGHTS (LB.) OF SELECTED SUB-GROUPS OF EWES IN TRIAL 2.

Group.	Did not lamb.	Lambed, lost lamb.	Lambed, reared lamb.
A—from Group 1 of Trial 1—			
Number	12	13	18
Greasy fleece weight	8·78	8·60	7·76
Clean fleece weight	5·05	5·22	4·54
B—from Group 3 of Trial 1—			
Number	2	2	13
Greasy fleece weight	9·26	9·05	7·87
Clean fleece weight	5·32	5·66	4·73
C—from Group 5 of Trial 1—			
Number	10	9	20
Greasy fleece weight	9·98	9·13	8·89
Clean fleece weight	6·06	5·60	5·13

Comparisons in terms of greasy and clean fleece weight were made also between selected sub-groups—ewes from untreated Group 1 of Trial 1 now in Group A; ewes from Group 3 (30 mg. Cu as glycinate) of Trial 1 now in Group B; and ewes from Group 5 (monthly sulphate group) of Trial 1 now in Group C. (These selected sub-groups had low, moderate and high liver copper concentrations at the beginning of Trial 2 as a result of their previous treatments during Trial 1.) These data are given in Table 12. Comparison on this basis emphasised the superior wool production in the proportion of Group C ewes from the originally copper-adequate Group 5. There was also a trend for Group B ewes to produce more wool than Group A ewes.

Table 13.

NUMBERS AND MEAN GREASY AND CLEAN FLEECE WEIGHTS (LB.) OF EWE AND WETHER LAMBS BORN TO EWES IN TRIAL 2.

Group.	Type.	Number of Lambs.	Mean Greasy Fleece Weight.		Mean Clean Fleece Weight.	
			Unadjusted.	Adjusted.*	Unadjusted.	Adjusted.*
A	Ewes ..	32	1·45	1·34	0·81	0·80
B	Ewes ..	17	1·28	1·25	0·72	0·73
C	Ewes ..	20	1·36	1·37	0·75	0·75
A	Wethers ..	11	1·25	1·22	0·70	0·73
B	Wethers ..	16	1·30	1·59	0·75	0·79
C	Wethers ..	12	1·37	1·45	0·82	0·83

* To compensate for minor differences in average ages, fleece weight was adjusted to a standard age of 116 days.

The fleece weights of lambs were adjusted to a standard age of 116 days (Table 13). There were no differences in fleece weight of lambs born to ewes in each of the three groups.

Fibre diameter, staple length and crimps per in. were determined on wool samples taken at the end of the trial in June 1955. The results are shown in Tables 14, 15 and 16. The findings were considered in terms of ewes and wethers from each of the three Groups A, B and C and in terms of selected sub-groups based on previous treatments during Trial 1. Ewes were considered also according to whether they did not lamb, lambed but lost lamb, or lambed and reared lamb. On wool from lambs, fibre diameter only was determined.

There was a suggestion that fibre diameter was greater in ewes from Group C, but this did not attain significance. The differences among wethers and among lambs were not significant. The fibre diameter of wool from ewes that reared lambs was very significantly ($P < 0{\cdot}001$) smaller than that of the other two categories of ewes.

Table 14.

MEAN FIBRE DIAMETER (MICRONS) OF WOOL FROM EWES, WETHERS AND LAMBS IN TRIAL 2.

Group.	Type.	Wethers or Dry ewes.	Lambed, lost lamb.	Lambed, reared lamb.
A	Ewes ..	21·0 (15)*	21·8 (17)	19·9 (33)
B	Ewes ..	21·0 (11)	21·8 (11)	19·5 (32)
C	Ewes ..	21·9 (17)	21·6 (16)	20·5 (30)
A, from Group 1, Trial 1 ..	Ewes ..	21·3 (12)	21·9 (13)	19·7 (18)
B, from Group 3, Trial 1 ..	Ewes ..	22·0 (2)	21·2 (2)	19·9 (13)
C, from Group 5, Trial 1 ..	Ewes ..	22·6 (11)	21·6 (10)	20·6 (21)
A	Wethers ..	21·8 (46)		
B	Wethers ..	22·2 (46)		
C	Wethers ..	21·5 (53)		
A, from Group 1, Trial 1 ..	Wethers ..	21·7 (34)		
B, from Group 3, Trial 1 ..	Wethers ..	22·3 (16)		
C, from Group 5, Trial 1 ..	Wethers ..	21·8 (31)		
A	Ewe lambs ..	18·0 (22)		
B	Ewe lambs ..	17·6 (17)		
C	Ewe lambs ..	18·2 (18)		
A	Wether lambs	17·2 (11)		
B	Wether lambs	17·8 (15)		
C	Wether lambs	18·0 (13)		

* Figures in brackets indicate the number of animals in each group on which the assessment was made.

Table 15.

MEAN STAPLE LENGTH (CM.) OF WOOL FROM EWES AND WETHERS IN TRIAL 2.

Group.	Type.	Wethers or Dry ewes.	Lambed, lost lamb.	Lambed, reared lamb.
A	Ewes	8·9 (15)*	9·4 (17)	8·9 (33)
B	Ewes	8·8 (11)	8·6 (11)	8·6 (32)
C	Ewes	8·9 (17)	9·0 (16)	8·7 (30)
A, from Group 1, Trial 1	Ewes	8·9 (12)	9·3 (13)	9·2 (18)
B, from Group 3, Trial 1	Ewes	9·0 (2)	8·8 (2)	8·5 (13)
C, from Group 5, Trial 1	Ewes	9·2 (11)	9·0 (10)	8·8 (21)
A	Wethers	9·1 (45)		
B	Wethers	8·8 (46)		
C	Wethers	8·8 (53)		
A, from Group 1, Trial 1	Wethers	9·1 (34)		
B, from Group 3, Trial 1	Wethers	8·8 (16)		
C, from Group 5, Trial 1	Wethers	8·7 (31)		

* Figures in brackets indicate the number of animals in each group on which the assessment was made.

Table 16.

MEAN CRIMPS PER INCH OF WOOL FROM EWES AND WETHERS IN TRIAL 2.

Group.	Type.	Wethers or Dry ewes.	Lambed, lost lamb.	Lambed, reared lamb.
A	Ewes	12·1 (15)*	12·0 (17)	12·8 (33)
B	Ewes	10·0 (11)	11·9 (11)	12·1 (32)
C	Ewes	10·6 (17)	10·9 (16)	11·6 (30)
A, from Group 1, Trial 1	Ewes	12·2 (12)	11·6 (13)	13·2 (18)
B, from Group 3, Trial 1	Ewes	11·0 (2)	10·0 (2)	11·9 (13)
C, from Group 5, Trial 1	Ewes	10·1 (11)	10·8 (10)	11·7 (21)
A	Wethers	11·7 (45)		
B	Wethers	10·8 (46)		
C	Wethers	12·2 (53)		
A, from Group 1, Trial 1	Wethers	11·6 (34)		
B, from Group 3, Trial 1	Wethers	10·8 (16)		
C, from Group 5, Trial 1	Wethers	12·2 (31)		

* Figures in brackets indicate the number of animals in each group on which the assessment was made.

There were no significant differences in staple length between groups or selected sub-groups.

In the ewes, after adjustment for lambing performance, Group A had significantly ($P < 0.01$) more crimps per in. than Group C. In the wethers, Group B had significantly ($P < 0.05$) fewer crimps per in. than the other two groups. This difference is not understood and as it occurred

in Group B cannot be related to the copper status of wethers. Ewes that reared their lambs had significantly ($P < 0{\cdot}01$) more crimps per in. than the other two groups.

The incidence of lesions in wool attributable to copper deficiency in each group at shearing in June is summarised in Table 17. Evidence of copper deficiency was obvious in 11 out of 110 fleeces in the untreated Group A, 2 out of 104 fleeces in Group B, and 1 out of 113 fleeces in Group C. These groups also contained 30, 15 and 15 fleeces respectively that showed slight evidence of copper deficiency.

Table 17.

NUMBER OF FLEECES SHOWING LESIONS OF COPPER DEFICIENCY IN TRIAL 2.

——	Group A.			Group B.			Group C.		
	Copper Deficiency Lesion.			Copper Deficiency Lesion.			Copper Deficiency Lesion.		
	Obvious.	Slight.	Normal.	Obvious.	Slight.	Normal.	Obvious.	Slight.	Normal.
Ewes did not lamb	2	3	1	..	2	10	..	3	12
Ewes lost lamb ..	2	8	6	..	2	10	..	1	14
Ewes reared lamb	1	7	23	1	3	29	..	2	27
Wethers	6	12	30	1	8	38	1	9	44
Totals—									
Number ..	11	31	69	2	15	87	1	15	97
Per cent. ..	10	27	63	2	14	84	1	13	86

A summary of the analyses of variance of data from Trial 2 is given in Table 18.

Table 18.

SUMMARY OF ANALYSES OF VARIANCE OF DATA FROM TRIAL 2.

Source of Variation.	Degrees of Freedom.	Mean Squares.					
		Gain in Body Weight Sept. 54—June 55.	Greasy Fleece Weight.	Clean Fleece Weight.	Fibre Diameter.	Crimps per Inch.	Staple Length.
Between groups (elim. fertility)	2	28·4	5·33*	3·02†	7·0	25·9**	1·79
Between fertility states (elim. groups)	2	2504·2***	10·48***	6·79**	58·1***	21·7**	1·32
Interaction ..	4	73·6*	0·27	0·29	0·20	3·63	0·92
Residual	171	27·8	1·21	1·04	2·61	4·41	0·82

† Approaching 5% probability level.
* Significant at 5% probability level.
** Significant at 1% probability level.
*** Significant at 0·1% probability level.

The essential findings on the effects of copper treatment upon wool production and quality, as detected in this trial, were:

(*a*) In wethers, there was no effect on clean or greasy fleece weights, fibre diameter, staple length or crimps per in.

(*b*) In ewes, clean and greasy fleece weights were increased by copper treatment, and this increase was enhanced when previous copper treatments in Trial 1 were considered.

(*c*) In ewes, copper treatment tended to increase fibre diameter, significantly reduced crimps per in. and had no influence on staple length.

(*d*) In both ewes and wethers, copper treatment reduced the incidence of visible copper-deficiency lesions in wool.

(3) Discussion.

In the 1954-55 season the summer rains started earlier and persisted longer than usual. This resulted in abundant pasture growth and a wide variety of herbage plants in autumn-winter.

The predominant vegetation again showed a low copper status. The molybdenum concentrations were appreciable, being particularly high in some herbages. The inorganic sulphate content was high. As in the previous trial, copper deficiency was attributable partly to the low copper content of grasses and partly to inhibition of copper metabolism in sheep by molybdenum in the presence of inorganic sulphate.

The treatment of these animals in Trial 1 had a marked influence on the liver copper reserves at the commencement of this trial. About two-thirds of the sheep in Group A were from the untreated control group in Trial 1, so the liver copper reserves were low in September. Group B, composed of previously treated Groups 2, 3 and 4 from Trial 1, showed moderately low copper reserves. Group C, composed largely of sheep from the monthly-treated Group 5, showed fair copper reserves.

At the conclusion of Trial 2 in June 1955, all animals in Group A showed a very low copper status. Although the mean levels were fairly satisfactory in Groups B and C, about half the animals examined in each group showed less than 80 p.p.m. Cu. As in Trial 1, treatment by subcutaneous injection tended to maintain slightly better liver copper concentrations than oral treatment at the same intervals. It was again apparent in this trial that treatments at 6-monthly intervals did not ensure adequate copper reserves.

In June 1955, liver copper concentrations were low in lambs born to ewes in each of the three groups. Sheep in Groups B and C received copper treatments in September and December 1954. It would therefore be expected that ewes in these two groups would have had good copper reserves both at mating and during pregnancy, and that lambs from these ewes would have

good reserves at birth. The low liver copper levels found in these lambs in June indicate that liver copper reserves present at birth were seriously depleted by four months of age.

The percentage of lambs marked to ewes mated was low in all groups. Poor fecundity and high neo-natal mortality are a feature of sheep breeding in north-western Queensland (Moule 1954). Ewes from the untreated control Group A had low liver copper reserves at the time of mating and even lower reserves nine months later in June 1955. Copper treatments given to Groups B and C in September and December would have ensured an adequate copper status during pregnancy. As there were no significant differences between groups in numbers of lambs born, birth weight, survival to marking or daily weight gain of lambs, it is concluded that copper supplementation did not influence reproductive performance in this trial.

As in Trial 1, copper supplementation had no measurable effect on body weight.

Ewes from Group C produced significantly more wool than those from Groups B and A. About two-thirds of the sheep in Group C were from the group drenched monthly during Trial 1 and thus had much higher liver copper reserves initially. Fleece weights were therefore examined in terms of the original untreated controls now in Group A, the original 30 mg. copper glycinate ewes now in Group B, and the original monthly drenched ewes now in Group C. Comparison on this basis enhanced the superior wool production of Group C and showed a tendency for Group B ewes to produce more wool than Group A. These findings emphasise the desirability of repeated copper treatments to build up good initial copper reserves, which could be then maintained by treatments given at intervals of about three months when sheep are normally handled for other purposes.

The differences in fleece weight among wethers were not significant, even when allowance was made for the previous treatments of the sheep in Trial 1. There was virtually no difference in fleece weights between biopsied and un-biopsied wethers, indicating that the operation had no adverse effect on wool growth. In lambs the mean rate of wool growth was 0·014 lb. per head per day, and this was unaffected by the sex of the lamb or by the group to which its dam belonged.

Wool samples from all fleeces were examined for fibre diameter, staple length and crimps per in. There was a suggestion that fibre diameter was greater in ewes from Group C. Ewes from Group A had significantly more crimps per in. than Group C. No other differences that could be attributed to copper treatments attained significance.

There were marked differences between groups in terms of incidence of lesions in wool indicative of copper deficiency. However, some fleeces from the treated Groups B and C showed evidence of slight copper deficiency, indicating that copper treatments at 6-monthly intervals did not ensure an adequate copper status in sheep in this locality.

Within each group of ewes, lambing performance and lactation had a significant influence on body weight, fleece weight, and the fibre diameter and crimps per in. in wool.

V. TRIAL 3 (1955-56)—GROWTH OF LAMBS AFTER WEANING.

A feature of Merino sheep in north-western Queensland is the smaller size compared with sheep of the same breeding in south-western Queensland. This has been attributed to poor growth of lambs. In Trial 1 the experimental sheep were 8–10 months of age at the commencement of the trial, and their liver copper concentrations were unexpectedly high (mean 160 p.p.m. Cu). No response in body weight was recorded from any of the copper treatments, but it was only during the last three months of the trial (June to September 1954) that liver copper reserves in the control group might be regarded as deficient, so no conclusions on the influence of copper supplementation on growth of sheep in this locality could be drawn.

In Trial 2 there were no significant differences between lambs born to copper-deficient and copper-treated ewes in birth weight, weight gain to marking age or body weight at a standard age of 116 days. In June 1955, liver copper reserves of a representative number of lambs, four months of age, were low irrespective of whether lambs were born to copper-supplemented or untreated ewes.

In September 1955, the 91 lambs born in Trial 2, now approximately seven months of age, were divided at random into two groups by allotting alternate sheep to each group as they were driven through a race. The two groups were:—

Group I. Untreated controls consisting of 26 ewes and 18 wethers.

Group II. Treated group consisting of 27 ewes and 20 wethers.

The treated group was drenched with copper sulphate solution equivalent to 140 mg. Cu in September 1955, 210 mg. Cu in October 1955, and 280 mg. Cu in March 1956.

The lambs were weighed after shearing in June 1955 and again in October 1955, March 1956, and after shearing in June 1956, as shown in Table 19. There were no significant differences in weight gains.

Table 19.

Mean Body Weights (lb.) of Weaner Lambs in Trial 3.

Group.	Type.	June 1955.*	October 1955.	March 1956.	June 1956.*
I	Ewes	34·7	52·5	74·9	75·0
II	Ewes	34·8	53·5	71·4	72·0
I	Wethers	35·9	54·1	78·7	74·0
II	Wethers	35·8	54·2	77·8	73·0

* Immediately after shearing.

The data on wool produced by these lambs at shearing in June 1956 are presented in Table 20. There were no significant differences between groups in terms of greasy or clean wool produced, but 10 out of 37 fleeces from the control group showed obvious evidence of copper deficiency, whereas none of the 35 fleeces from the treated lambs showed lesions.

Table 20.

Mean Greasy and Clean Fleece Weights and Number of Fleeces Showing Lesions of Copper Deficiency Among Weaner Lambs in Trial 3 at June 1956.

Group.	Type.	Number of Sheep.	Greasy Fleece (lb.).	Clean Fleece (lb.).	Copper Deficiency Lesions.		
					Obvious.	Slight.	Normal.
I	Ewes	21	8·9	5·0	9	7	5
II	Ewes	18	8·8	4·6	..	6	12
I	Wethers ..	16	9·5	5·1	1	10	5
II	Wethers ..	17	9·6	5·3	..	5	12

Thus, three copper sulphate drenches given during 12 months to weaner lambs which initially had very low liver copper concentrations (Table 7) were sufficient to substantially prevent visible copper-deficiency lesions in the wool but had no effect on body weight or greasy or clean wool production.

VI. GENERAL DISCUSSION.

In this locality of north-western Queensland, copper deficiency in sheep was found to be due partly to the low copper and partly to the high molybdenum and inorganic sulphate content of the predominant vegetation. The period of greatest depletion of liver copper reserves in sheep was autumn-winter, when herbage plants high in molybdenum and very high in inorganic sulphate were abundant and readily eaten by sheep.

In these trials copper supplementation of ewes had no influence on reproductive rate, birth-weight of lams, neo-natal mortality or growth rate of lambs to marking. Copper supplementation of weaners did not affect their growth rate.

Fleece weights of sheep receiving copper were higher than those of control sheep, but the differences were slight except in orally treated ewes. After eliminating differences due to lambing, orally treated ewes produced about 0·5 lb. per head more greasy wool than the controls. This orally treated group comprised mainly sheep with high initial liver copper levels resulting from treatment once a month during Trial 1, and the findings thus tend to indicate a response to *prolonged* copper treatment rather than the superiority of oral treatment.

There was a much lower incidence of lesions in wool due to copper deficiency in the fleeces of sheep from all treated groups, indicating that copper supplementation had improved wool quality.

Six-monthly treatment of sheep, either orally or by subcutaneous injection, did not ensure an adequate liver copper reserve, particularly in the months when herbage plants predominated.

In spite of copper treatments of ewes which should have ensured adequate liver copper reserves in lambs at birth, the liver copper concentrations were low in lambs at four months of age.

Based on these trials, recommendations for the prevention of copper deficiency in sheep in this area are as follows:

(1) Establish a good initial reserve of copper by three treatments at fortnightly or monthly intervals.

(2) Maintain these copper reserves by treatment at approximately 3-monthly intervals at times when sheep are normally handled—e.g., for shearing, crutching, jetting, marking and weaning.

(3) Lambs must be treated at marking and thereafter at 3-monthly intervals.

At the dose rates used in these trials copper glycinate given subcutaneously was not markedly superior to copper sulphate given orally. Sutherland, Moule and Harvey (1955) showed that there was some risk of toxicity to weaners at dose rates exceeding 30 mg. Cu as copper glycinate subcutaneously or 200 mg. Cu as copper sulphate orally.

VII. ACKNOWLEDGEMENTS.

The authors acknowledge indebtedness to the owner of the property, who generously provided the experimental flock, facilities and considerable assistance in all stages of this work.

The statistical analyses were made by Mr. A. W. Beattie, B.Sc.Agr., whose helpful suggestions proved most valuable in planning and executing the work. Field officers of the Sheep and Wool Branch assisted in the field work and carried out lambing observations. The staff of the Biochemical Branch assisted in the chemical analyses. The Chief Government Botanist (Mr. S. L. Everist, B.Sc.) identified pasture plants. The wool samples were examined by the staff of the Wool Biology Laboratory.

The financial assistance received from the Australian Wool Research Trust Fund is also gratefully acknowledged.

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STUDIES OF THE COCCOIDEA

8. THREE NEW GENERA AND SIXTEEN NEW SPECIES OF ASPIDIOTINI

By A. R. BRIMBLECOMBE, M.Sc., Senior Entomologist, Division of Plant Industry.

SUMMARY.

New generic names proposed in the Aspidiotini are Diaspidopus, Diastolaspis, **and** Neoclavaspis. **Species described as new are** Aspidiotus queenslandicus, Chrysomphalus trifasciculatus, Clavaspis quadriloba, Diaspidiotus evexus, Diaspidopus distinctus, Diastolaspis novata, Greeniella capitata, G. ornata, Monaonidiella parva, Myrtophila pseudadnatae, Neoclavaspis duplex, Pseudotargionia asymmetrica, P. isaensis, Remotaspidiotus albus, R. reconditus, **and** R. squamosus. **Fourteen of these species are from Queensland, and one each from Northern Territory and Victoria.**

Aspidiotus queenslandicus n.sp.

Locality and host.—Queensland: Beenleigh, on *Acronychia laevis* Forst., May 1956.

Habit.—Insects mostly single on leaf surfaces. Female scale circular, 2·5 mm. diameter, dark fawn in colour. Pellicles orange coloured.

Recognition characters.—Adult female membranous, broadly turbinate, length of slide specimen 1·8 mm., width 1·2 mm. Pygidium large, apex broadly rounded, with three pairs of parallel lobes. Median lobes longer than wide; margins subparallel but each with a large subapical indentation; apex rounded; separated by slightly more than a lobe's width. Second pair of lobes comparable to but smaller than the median lobes, with the subapical indentation less pronounced, separated by slightly more than a medium lobe's width. Third pair of lobes similar to but slightly smaller than the second pair and separated by twice a second lobe's width. Basal scleroses not prominent, as long as but narrower than the median lobes. Paraphyses absent. Plates large and conspicuous; two in the median interlobal space, elongate, as long as the lobes, apically fimbriate; two in the first interlobal space and three in the second similar to those in the median space except the branching tending to become lateral; seven plates anterior to the third lobe, broad, the posterior five with latero-apical fimbriation, anterior two smaller and less branched, the posterior branch on all or most plates acicular and

(Figs. 1 and 2.)

Fig. 1.

Aspidiotus queenslandicus. Outline of Body. (× 50.)

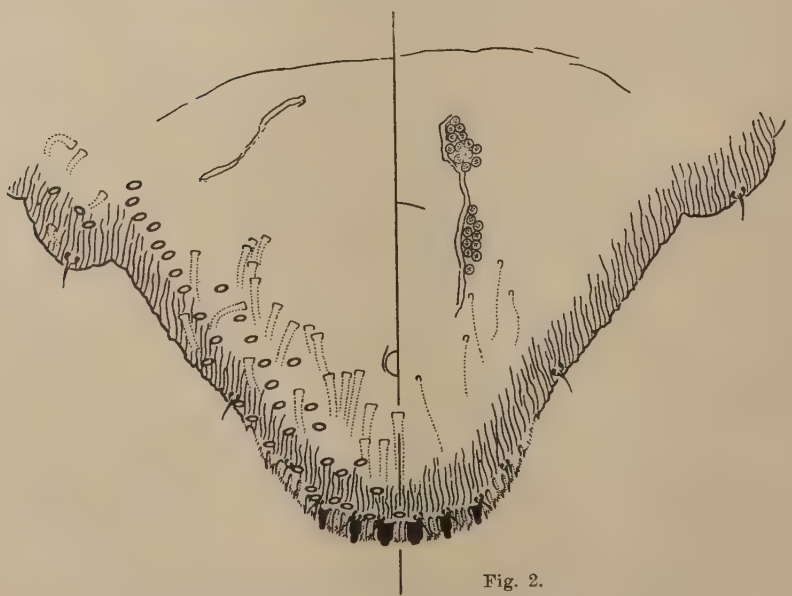

Fig. 2.

Aspidiotus queenslandicus. Enlargement of Pygidium. (× 185.)

separated by a deep incision. Spines normal. Dorsal macroducts moderately long, three-quarters of the distance from the median lobes to the anal opening; one in the median area; three or four in the first duct furrow; seven in the second furrow; 10 in the third furrow; 12 in the fourth furrow; nine or 10 submarginally on the fourth abdominal segment; 12 to 14 on the third segment; and up to 16 on the second segment. Perivulvar pores in four groups, 12 to 14 in the anterior laterals and seven to 10 in the posterior laterals. Anal opening of moderate size, oval, four to five time its long axis from the median lobes. Vulva twice the distance of the anal opening from the lobes.

Notes.—In some specimens the plates in the median, first and second interlobal spaces are slightly longer than the median lobes. Dorsal macroducts on the prepygidial segments vary in number; there may be none or up to seven on the first abdominal segment. A small dome-like lateral tubercle may be present and the anterior pygidial margin may have some scattered small serrations. The basal scleroses are sometimes indistinct.

This species has some of the features of an *Octaspidiotus* but the absence of the fourth lobe excludes it from this genus. In the genus *Aspidiotus* it has affinity with *A. destructor* Newstead but differs in having macroducts on prepygidial abdominal segments.

Type Reg. No. T.5692 and paratypes Nos. T.5693 to T.5695 in the Queensland Museum.

Chrysomphalus trifasciculatus n.sp.

(Figs. 3 and 4.)

Locality and host.—South Queensland: on *Eucalyptus* sp., Mar. 145.

Habit.—Insects numerous on bark of the tree trunk. Female scale circular, 1·5–2·0 mm. diameter, light fawn, pellicles orange coloured.

Recognition characters.—Adult female broadly pyriform to subreniform, membranous, length 1·0 mm., width 1·0 mm. Pygidium demarcated by dorsal longitudinal fingerprint thickening; apex broadly rounded, with three pairs of lobes and a slight marginal sclerotization in the position of the fourth lobe. Median lobes wider than long, separated by one-third of a lobe's width; inner margins subparallel, outer margins curved, apex broadly curved and entire. Second pair of lobes similar to but smaller than the median lobes and separated from them by one-third of a median lobe's width. Third pair of lobes smaller, triangular, apically pointed. Basal scleroses absent. Paraphyses in the median, first and second interlobal areas; short in the median area; twice as long as the median lobes in the first interlobal area, the inner wider than the outer and slightly longer; only the inner paraphysis distinct in the second interlobal area, as long as the median lobes. Plates present in the median, first, second

Fig. 3.

Chrysomphalus trifasciculatus. Outline of Body. (× 120.)

and third interlobal spaces; two plates in the median space, slender and apically bifid; two plates in the first space, apically branched; three plates in the second space, the branching more lateral; three plates in the third space, more robust and branched. Dorsal macroducts more than three times the distance from the median lobes to the anal opening in the first duct furrow; duct heads moderately broad; orifices moderately large in segmental series; five or six in the first duct furrow between the paraphyses, seven in the second furrow, eight in the third furrow, nine on the fourth abdominal segment, five or six on the third segment and up to five on the second segment, with shorter and smaller ducts extending anteriorly near the margin. Median and lateral pygidial scars present but not prominent, paravulvar folds not strongly developed. Perivulvar pores absent. Anal opening small, slightly more than its own diameter from the bases of the median lobes, with a distinct anal groove. Vulva six times the distance of the anal opening from the median lobes.

Notes.—A small short thoracic tubercle with jagged apex discernible in some specimens. The sclerotization in the position of the fourth lobe may be indistinct; when present, the margin may be finely serrate. The number of ducts on prepygidial abdominal segments may vary from one to six on the second segment, from six to nine on the third segment and from seven to nine on the fourth segment. The outer paraphysis in the second interlobal area may sometimes be evident but is always smaller than the inner paraphysis.

Fig. 4.

Chrysomphalus trifasciculatus. Enlargement of Pygidium. (× 400.)

This species resembles *C. bifasciculatus* Ferris but differs in the absence of perivulvar pores and the presence of groups of dorsal ducts on three prepygidial abdominal segments.

Other material considered to be this species is labelled in the C.S.I.R.O. collection, Canberra, as follows (*a*) "A. (*Aspidiotus*) *aurantii?* Mask., Blue Gum, Wyong, McPherson, W.W.F." and (*b*) "*Aspidiotus fuscus* Crookwell, N.S.W."

Type Reg. No. T.5696 and paratypes Nos. T.5697 to T.5699 in the Queensland Museum.

Clavaspis quadriloba n.sp.

(Figs. 5 and 6.)

Locality and host.—Queensland: Yarraman, on *Owenia venosa* F. Muell., May 1947.

Habit.—Insects sparse on twigs of host, details of scale not available.

Recognition characters.—Adult female broadly turbinate, membranous, length 1·0 mm., width 0·75 mm. Pygidium large, apex obtuse with four pairs of lobes. Median lobes slightly convergent, almost contiguous apically, outer

margins indented, apex rounded. Second pair of lobes similar to but much smaller than the median lobes, separated from these by half a second lobe's width. Third pair of lobes smaller, as triangular points, separated from the second by almost a second lobe's width. Fourth pair of lobes subconical points, separated from the third lobes by more than the distance of the third from the median lobes. Basal scleroses arising from the inner basal part of the median lobes, longer than the lobes. Paraphyses in the first and second interlobal areas; the inner paraphysis of the first area more than twice the length of the median lobes and apically enlarged, the outer paraphysis indistinct, the

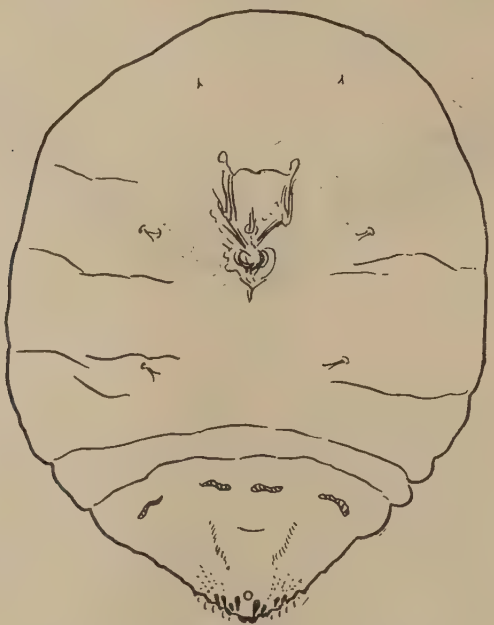

Fig. 5.

Clavaspis quadriloba. Outline of Body. (× 95.)

pair in the second area equal in length, longer than the median lobes. Plates in the first, second and third interlobal spaces; two in the first space, slender, as long as the second lobes; two in the second space, longer than the lobes; three in the third space, broad and branched. Spines adjacent to the median lobes shorter than the lobes, other spines longer. Dorsal macroducts long, slender, reaching almost to the vulva in the first furrow; orifices in segmental series. Perivulvar pores absent. Median and lateral scars distinct. Paravulvar folds present but not prominent. Anal opening small, within the apices of the basal scleroses. Vulva five times the distance of the anal opening from the median lobes.

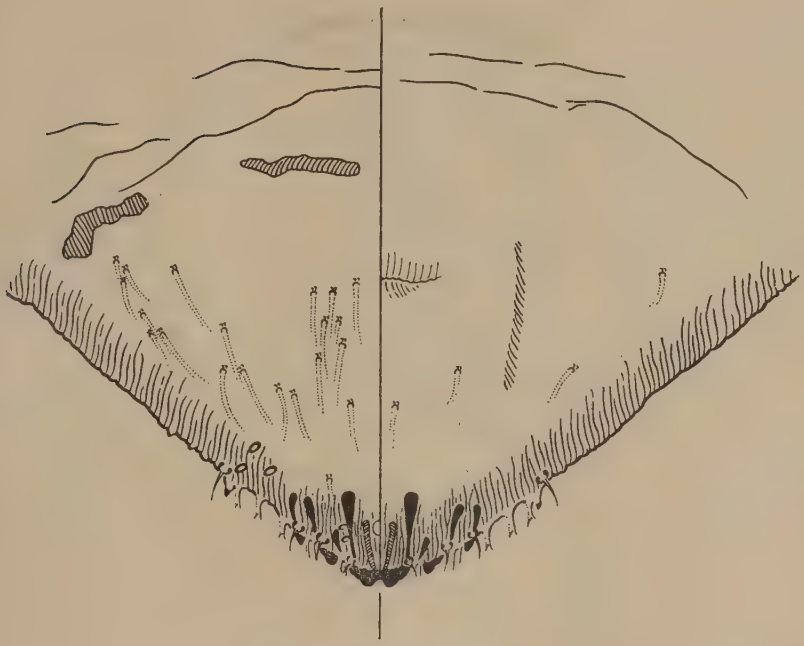

Fig. 6.

Clavaspis quadriloba. Enlargement of Pygidium. (× 297.)

Notes.—The basal scleroses are more or less in the position of median paraphyses but they appear to be continuations of the median lobes.

This species has affinity with *C. subfervens* (Green) and *C. dentata* Ferris, but differs from *C. subfervens* in having four pairs of lobes and from *C. dentata* in having larger and branched plates in the third interlobal space.

Type Reg. No. T.5700 and paratype No. T.5701 in the Queensland Museum.

Diaspidiotus evexus n.sp.

(Figs. 7 and 8.)

Locality and host.—Northern Territory: Alice Springs, on *Eremophila sturtii* R.Br., May 1954 (L. S. Smith).

Habit.—Insects mostly single on leaves and twigs. Female scale circular, 0·85 mm. diameter, dull white to light fawn colour, pellicles central, dark orange.

Fig. 7.

Diaspidiotus evexus. Outline of Body. (×145.)

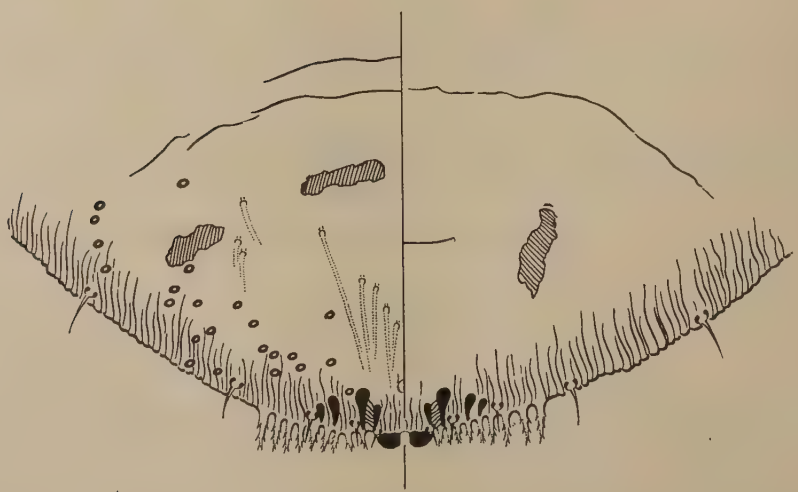

Fig. 8.

Diaspidiotus evexus. Enlargement of Pygidium. (× 335.)

Recognition characters.—Adult female circular to broadly oval, membranous, length of slide specimen 0·7 mm., width 0·6 mm. Pygidium comparatively large, wide, apex broadly rounded with median pair of lobes only. Lobes as wide as or slightly wider than long, separated by one-third of a lobe's width; inner and outer margins almost straight, subparallel; apex as a rounded point between two indentations. Basal scleroses absent. Paraphyses in the first and second interlobal areas; the pair in the first interlobal area elongate, longer than the lobes, the outer with the apex slightly enlarged; paraphyses in the second interlobal area shorter than those in the first interlobal area. Plates in the first, second and third interlobal spaces totalling nine, longer than the lobes, longest anteriorly, of similar general shape, apices pointed, several short sharp lateral branches. Spines adjacent to the lobes as long as the lobes, other pygidial spines longer. Dorsal ducts long and slender, in the median area three times the distance of the anal opening from the bases of the lobes, heads small; duct orifices normal, in segmental series, two in the median interlobal area, two or three in the first interlobal area, six to eight in the second duct furrow and eight to 10 in the third furrow. Perivulvar pores absent. Paravulvar folds, median and lateral dorsal scars prominent. Anal opening small, two-and-a-half to three times the length of the lobes from the bases of the lobes. A small dome-shaped process marginally on the thorax.

Notes.—In some specimens the median lobes may be apically bluntly rounded with little indication of the indentations. This species morphologically has some resemblance to *D. liquidambaris* (Kotinsky), but differs from that species in general shape and the more robust plates which also have greater branching.

Type Reg. No. T.5702 and paratypes Nos. T.5703 and T.5704 in the Queensland Museum.

DIASPIDOPUS new genus.

Generic type.—Diaspidopus distinctus n.sp.

Characters.—Adult female subcircular, with a deep thoracic constriction. Pygidium with median lobes widely separated. Basal scleroses, paraphyses and plates absent. Elongate spine-like structures between the lobes. Groups of very large ducts or megaducts opening on pygidial apex. Dorsal ducts of moderate length. Perivulvar pores absent. Anal opening small. Pygidial margin serrate. Anterior spiracles with associated pores.

Notes.—This genus has relationship to *Pseudotargionia* and related genera with a deep thoracic constriction and heavy sclerotization, but the very large and long ducts or megaducts are unique.

Diaspidopus distinctus n.sp.

(Figs. 9 and 10.)

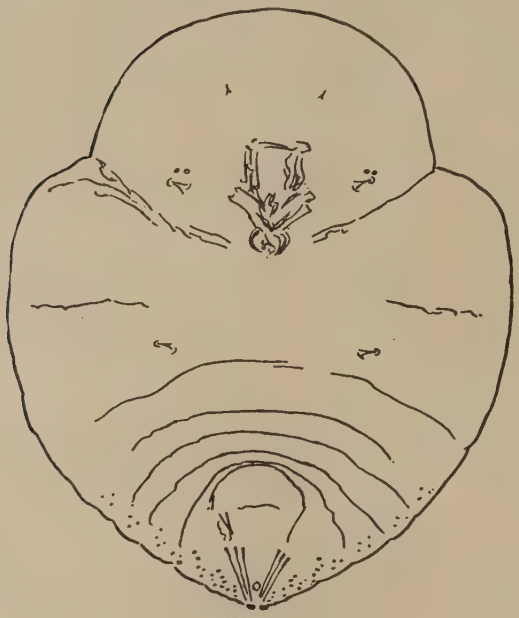

Fig. 9.

Diaspidopus distinctus. Outline of Body. (× 120.)

Locality and host.—Queensland: Glenmorgan, on *Homoranthus virgatus* A.Cunn. ex Schau., July 1957 (A.W.S. May).

Habit.—Insects clustered in axils of the small leaves amongst loose cottony filaments. Scale of adult female circular, white, embedded in the mealy filaments, up to 0·8 mm. diameter, surmounted by orange coloured pellicles, loose meal up to 2·0 mm. diameter.

Recognition characters.—Adult female subcircular, with a large thoracic constriction; anterior portion dome-shaped; posterior portion much wider, almost three-quarters of a semicircle; length of slide specimen 0·6 mm., width 0·5 mm. Pygidium widely obtuse with median pair of lobes only. Lobes wider than long, inner margin basally constricted, outer margin basally enlarged and merging into pygidial serrations; apically broadly rounded; separated by one-and-a-half times a lobe's width. Basal scleroses, paraphyses and plates absent. A pair of elongate spine-like structures evenly spaced between the lobes, longer than the lobes, other spines shorter than the lobes. Two groups of three very large ducts or megaducts as long as the vulva is distant from the lobes, opening evenly by a jet-like orifices between the lobes, apical thickening surrounding orifices extends back along the ducts; normal

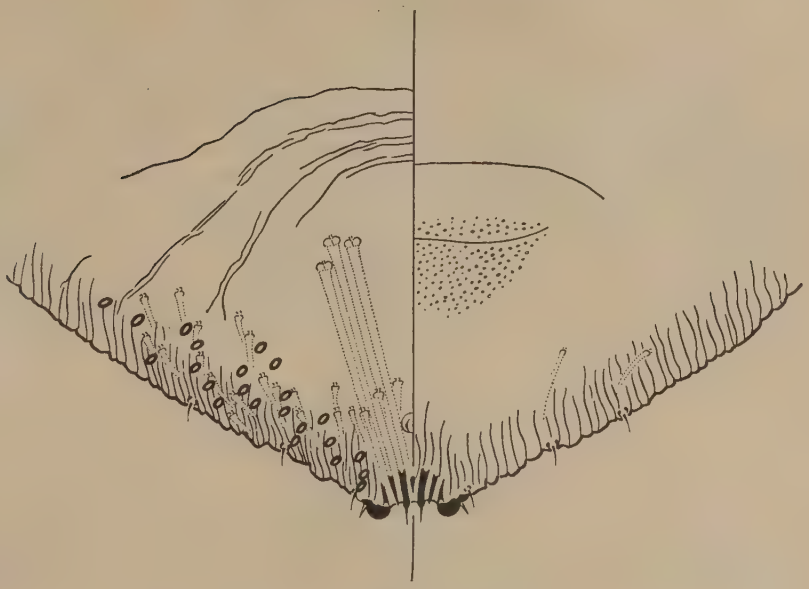

Fig. 10.

Diaspidopus distinctus. Enlargement of Pygidium. (× 315.)

dorsal ducts numerous, in the median region exceeding the distance to the anal opening, orifices oblique, two or three on each side of the median interlobal area, three in the first duct furrow; five or six in the second furrow with three in an intermediate row; five in the third furrow with three in an intermediate row; some ducts on other abdominal segments and becoming smaller anteriorly. Perivulvar pores absent. Anal opening small, oval, two-and-a-half times the length of the lobes from the lobes. Vulva very wide, three times the distance of the anal opening from the lobes. Pygidial margin irregularly serrate. Anterior spiracles with two or three associated pores. Pygidium ventrally with a stippled sclerotization. Body of mature females heavily sclerotized.

Notes.—In some specimens a lobe-like structure occurs in the position of the second lobes but this is part of the marginal serration. The basal enlargement of the outer margin of the lobe may give the appearance of a large lateral indentation. Some specimens have a sharp, short but wide lateral thoracic spur. The rather large median ducts or megaducts possibly produce the mealy filaments associated with these insects. These ducts are unique in the family Diaspididae; otherwise the species has some relationship to the *Pseudaonidia* group. The second-stage female has two pairs of megaducts.

Type Reg. No. T.5705 and paratypes Nos. T.5706 to T.5708 in the Queensland Museum.

DIASTOLASPIS new genus.

Generic type.—Diastolaspis novata n.sp.

Characters.—Adult female with a deep thoracic constriction. Pygidium with median pair of lobes only; pygidial margin with serrations. Paraphyses in the first and second interlobal areas. Plates in the first, second and third interlobal spaces, mostly branched. Dorsal ducts long and slender. Perivulvar pores absent. Anal opening small. Anterior spiracles without associated pores. Pygidium dorsally with reticulate sclerotization.

Notes.—This genus has close affinity with *Pseudotargionia* but differs in having long ducts, a toothed pygidial margin, no pores associated with the anterior spiracles, contiguous median lobes and four longitudinal dense bands ventrally on the pygidium.

Diastolaspis novata n.sp.

(Figs. 11 and 12.)

Locality and host.—Victoria: Lake Hattah, on *Eucalyptus* sp., 1916.

Habit.—Insects scattered on foliage. Scale of adult female circular, diameter 1·5 mm., dark fawn in colour with a light fawn margin. First pellicle central, dark olive green; second pellicle covered with a pale suffusion.

Fig. 11.

Diastolaspis novata. Outline of Body. (× 70.)

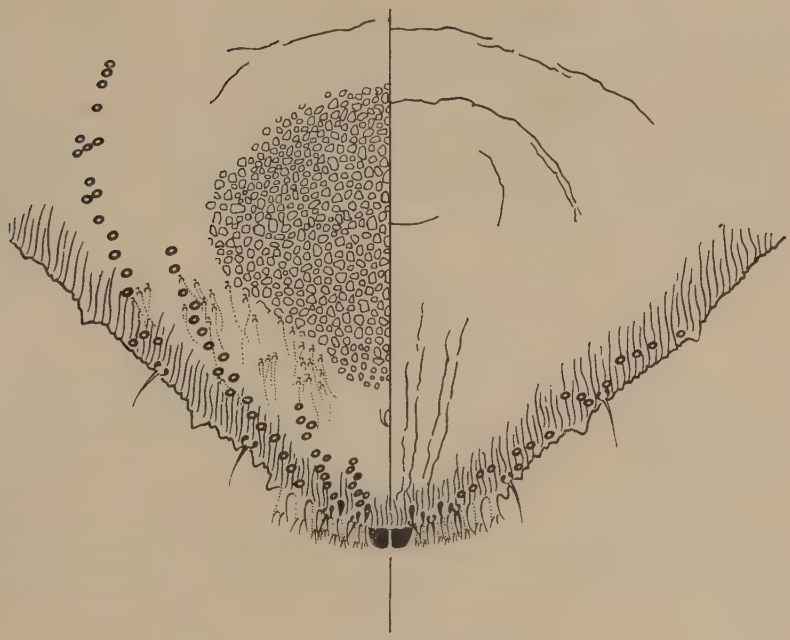

Fig. 12.

Diastolaspis novata. Enlargement of Pygidium. (× 200.)

Recognition characters.—Adult female large, length of slide specimen 1·2 mm., width 1·0 mm., with a deep thoracic constriction; anterior portion dome-shaped; posterior portion sub-triangular with lateral sides slightly curved. Pygidium large, apex broadly rounded, with median pair of lobes only but margin with sclerotized teeth. Lobes as long as or slightly longer than wide, contiguous, outer margins convergent to each other, inner and outer margins simple, apex broadly rounded. Dense lobe sclerotization grades into body but definite basal scleroses absent. Paraphyses as small uneven pairs in the first and second interlobal areas. Spines adjacent to the lobes shorter than the lobes, other spines much longer. Plates in the first, second and third interlobal spaces; two plates in the first interlobal space, as long as the lobes, slender, branched; three plates in the second interlobal space, longer than the lobes, anterior plate slender, others variously branched; three plates in the third interlobal space apically branched, longer than the lobes, the posterior one slender, the other two wider. Dorsal ducts long, reaching beyond the anal opening in the median area, slender, heads small, orifices in segmental series with some intermediate orifices; six or seven orifices in the first duct furrow, 10 to 14 in the second, 18 to 20 in the third. Perivulvar pores absent. Anal opening small, oval, five times length of lobes from the bases of the lobes

Pygidium ventrally with four longitudinal scars radiating from the apex, dorsally with a reticulate sclerotization. Body of mature specimens heavily sclerotized. Anterior spiracles without associated pores.

Notes.—Pygidial segments, particularly 6 and 7, may have a pronounced sclerotized tooth with intervening serrations. The lobes may be so close as to appear yoked basally. The convergence of the outer margins of the lobes may give the lobes themselves the appearance of apical convergence. The anterior paraphysis in each interlobal area may be small and not obvious as a paraphysis.

Type slide and unmounted material in C.S.I.R.O. collection, Canberra; paratypes Reg. Nos. T.5709 and T.5710 in the Queensland Museum.

Greeniella ornata n.sp.

(Figs. 13 to 15.)

Locality and host.—Queensland: Nambour, on *Callistemon salignus* (Sm.) DC., July 1956 (W.A. Smith.)

Habit.—Insects common, mostly lining the midrib of leaves. Scale of adult female circular, 0·9 mm. diameter, convex, black with margin dark fawn; second pellicle dark brown to black, completely covering adult female; first pellicle black, central, with a series of pale lateral filaments, and a pair dorsally.

Fig. 13.

Greeniella ornata. Outline of Body. (× 120.)

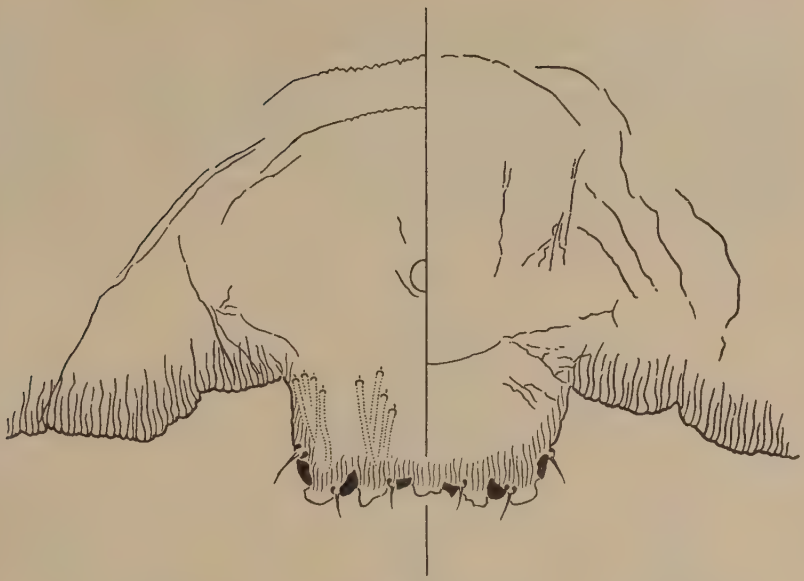

Fig. 14.

Greeniella ornata. Enlargement of Pygidium. (× 330.)

Recognition characters.—Adult female membranous, circular except posteriorly, length of slide specimen 0·7 mm., width 0·7 mm. Pygidium with sides posteriorly convergent, apex truncated. Three pairs of irregular lobes approximately evenly spaced, the third pair anterior to the latero-posterior angles of the pygidium. Basal scleroses and paraphyses absent. Derm between the lobes irregular and not as normal plates. Spines prominent. Ducts long and slender, four in the first duct furrow, four or five in the second furrow; orifices at or near the margin. Anal opening round, five to six times its diameter distant from posterior margin. Vulva posterior to the anal opening. Perivulvar pores absent.

Second stage female broadly oval. Pygidium rounded with four pairs of lobes. Median lobes less than half as wide as long, margins entire and subparallel, apex rounded, separated by slightly more than a lobe's length. Second pair of lobes similar to the median lobes but twice as wide, separated from the median by a lobe's length. Third pair of lobes large, longer than the second pair, three times wider than long, margin finely serrate, separated from the second by the length of the latter. Fourth pair of lobes twice as wide as long, triangular, margin very finely serrate, separated from the third, half the width of the fourth. Basal scleroses absent. Paraphyses as an uneven pair in the second interlobal area, elongate. Plates in the median, first, second and third interlobal spaces. Two plates in the median space, simple,

slightly longer than the lobes; two plates in the first space, similar to those in the median space but apically slightly dilated; three plates in the second space, apically branched, three plates in the third space, slightly apically enlarged or branched; one or two small derm processes anterior to the fourth lobe and an uneven pair on the posterior marginal angle of the fourth abdominal segment. Anal opening round, twice the length of the median lobes distant from the lobes and in the posterior angle of two longitudinal thickened folds. Ducts slender and long.

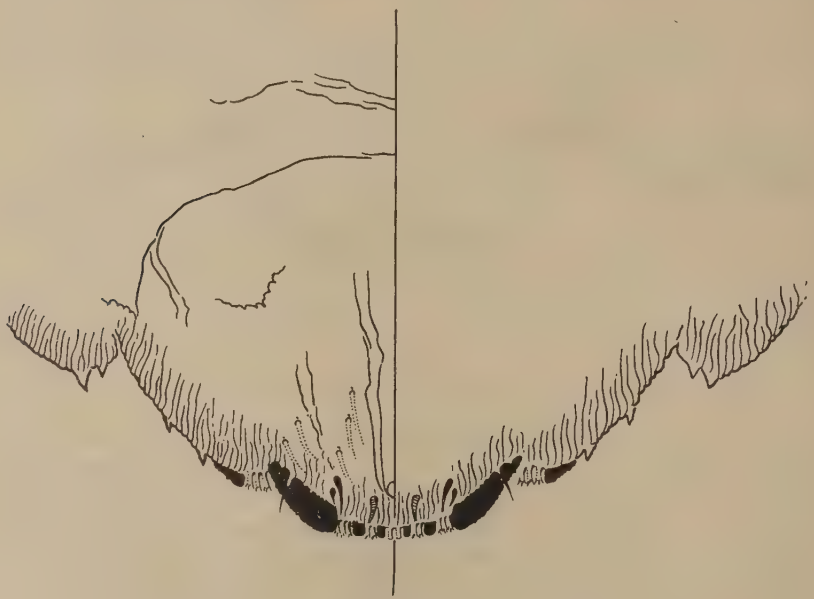

Fig. 15.

Greeniella ornata. Second-stage Female. Enlargement of Pygidium. (× 350.)

Notes.—On some adult specimens there are a few small peg-like derm processes on the prepygidial abdominal margin. In the second-stage female there are sclerotic thickenings indicative of paraphyses in the first interlobal area.

This species resembles *G. truncata* (Green and Laing) but differs in the adult stage in that the pygidium is larger, prominent and set in a large body indentation. In the second stage *G. truncata* has more slender median lobes, the second lobes are large and not resembling the median and the third pair are only slightly larger than the second pair.

Type Reg. No. T.5711 and paratypes Nos. T.5712 to T.5714 in the Queensland Museum.

Greeniella capitata n.sp.

(Figs. 16 to 18.)

Locality and host.—Queensland: Brisbane River, on *Hemicyclia australasica* Muell. Arg., prior to 1900 (F. M. Bailey per L. S. Smith).

Habit.—Insects scattered along the midrib of leaves. Second pellicle circular, 0·75 mm. diameter, completely covering the adult body, convex, black with a slight greyish suffusion and a narrow fawn coloured margin; first pellicle central and black.

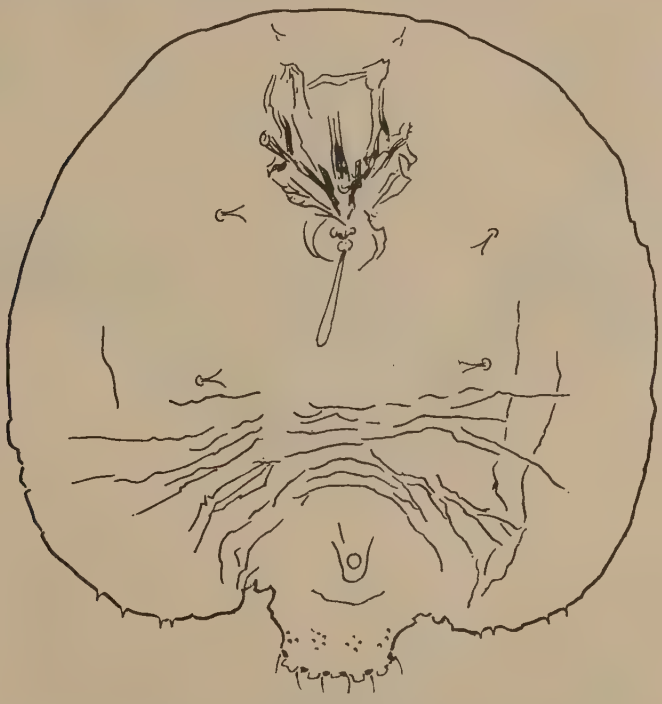

Fig. 16.

Greeniella capitata. Outline of Body. (× 180.)

Recognition characters.—Adult female membranous, subcircular, length and width of slide specimen 0·5 mm. Pygidium with the lateral margins posteriorly convergent; apex truncated with three pairs of irregular and independent lobes, almost evenly spaced, the third pair anterior to the latero-posterior angles of the pygidium. Basal scleroses and paraphyses absent. Normal plates absent but irregular derm projections present in the median first and second interlobal spaces. Spines prominent. Dorsal ducts slender, reaching one-third of the distance from the lobes to the anal opening; six or

seven in the first duct furrow, three or four in the second; orifices at or near the margin. Anal opening round, seven times its diameter from the posterior margin. Vulva posterior to the anal opening. Perivulvar pores absent. Prepygidial abdominal segments with conical marginal processes.

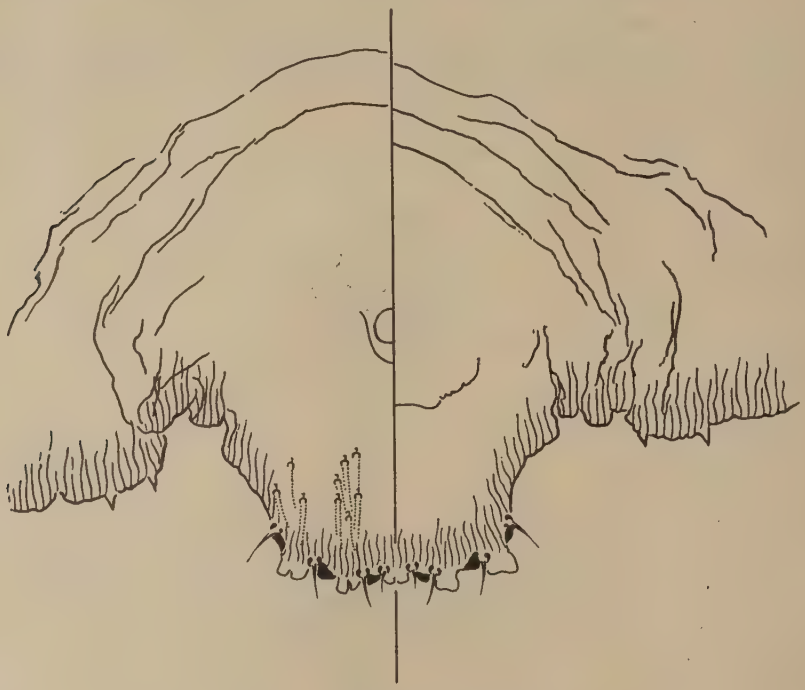

Fig. 17.

Greeniella capitata. Enlargement of Pygidium. (× 390.)

Second-stage female broadly oval. Pygidium broadly rounded, with four pairs of lobes. Median lobes longer than wide, separated by a lobe's length; margins subparallel; apex rounded. Second pair of lobes as long as the median lobes and as wide or slightly wider than long; apex rounded; separated from the median lobes by slightly more than a median lobe's width. Third pair of lobes large, longer than the second pair, three times wider than long, margin finely serrate, separated from the second pair by the length of a second lobe. Fourth pair of lobes wider than long, triangular, margin finely serrate, separated from the third pair by one-half to two-thirds of a third lobe's width. Basal scleroses absent. Paraphyses single, on the inner side of the first and second interlobal areas. Plates in the median, first and second interlobal spaces; two in the median space, slightly longer than the lobes;

two plates in the first space, apex dilated; three plates in the second space, the median and third apically branched; three plates in the third space also with the median and third apically branched. Two derm processes occur beyond the fourth lobe and one posterior to the lateral angle of the fourth abdominal segment. Anal opening round, its own diameter distant from the median lobes and in the posterior angle of two longitudinal folds. Dorsal ducts slender and long.

The first-stage nymph has a reticulated pattern between the ocelli.

Fig. 18.

Greeniella capitata. Second-stage Female. Enlargement of Pygidium. (× 385.)

Notes.—The specimens available did not show the pale filaments on the first pellicle normally occurring in this genus, possibly due to abrasion.

In some mature adult females the pygidium is in a large body indentation and the anal opening may be only six times its diameter from the posterior margin. The paraphysis sclerotization in the second-stage female is submarginal and may be apically divided.

The adult female of this species closely resembles that of *G. ornata,* but differs in that the latter has only four ducts in the first duct furrow and the marginal processes on the prepygidial abdominal segments are not noticeable or very small. The resemblance is also evident in the second-stage female

but the second pair of lobes are larger, the fourth pair of lobes are a greater distance from the third pair, the anal opening is closer to the lobes and the plates in the third interlobal space are more widely placed. The third lobes are marginally slightly concave or almost straight, while in *G. ornata* this margin is strongly convex.

Type Reg. No. T.5715 and paratypes Nos. T.5716 to T.5718 in the Queensland Museum.

Monaonidiella parva n.sp.

(Figs. 19 and 20.)

Locality and host. —Queensland: Beerwah, on *Banksia robur* Cav., Apr. 1953 (R. P. Kleinschmidt).

Habit.—Insects sparse on the under leaf surface. Scales white, circular, 1·2 mm. in diameter.

Recognition characters.—Adult female broadly pyriform to subcircular, membranous, length of slide specimen 0·8 mm., width 0·7 mm. Pygidium apically broadly curved, with median pair of lobes only. Lobes slightly

Fig. 19.

Monaonidiella parva. Outline of Body. (× 120.)

Fig. 20.

Monaonidiella parva. Enlargement of Pygidium. (× 350.)

longer than wide, inner and outer margins subparallel, apex with two indentations. Basal scleroses as long as the lobes and one-half to two-thirds as wide. Paraphyses absent. Plates in the first, second, third and fourth interlobal spaces; two in the first space as long as or slightly longer than the lobes and slightly branched apically; three in the second space, first simple, the others apically branched; three in the third space and two in the fourth. Spines longer than the lobes. Dorsal ducts few, not in distinct segmental rows, length in the first furrow two-thirds of the distance between the lobes and anal opening; two or three in the first duct furrow; five in the second furrow with a few between the first and second furrows. Perivulvar pores in three or four groups; two pores in each of the anterior groups, one or two in the posterior groups. Anal opening moderately large, twice the length of the lobes distant from the lobes. Paravulvar folds broadly curved.

Notes.—One of the posterior groups of perivulvar pores may be absent. A small low dome-shaped lateral thoracic tubercle may be present.

This species resembles *M. cerata* (Maskell) but differs in having posterior groups of perivulvar pores, fewer dorsal ducts, and plates in the fourth interlobal space.

Type Reg. No. T.5719 and paratype No. T.5720 in the Queensland Museum.

Myrtophila pseudadnatae n.sp.

(Figs. 21 and 22.)

Locality and host.—Queensland: Mt. Isa, on *Melaleuca bracteata* F. Muell., Feb. 1958 (H. J. Lavery).

Habit.—Insects mostly single on foliage. Scales circular, convex, dull whitish in colour, pellicles dark; 0·6 mm. diameter.

Recognition characters.—Adult female with a deep thoracic constriction, subcircular; anterior portion a raised dome-shape, lateral margins posteriorly convergent; posterior portion semicircular; length of slide specimen 0·5 mm., width 0·45 mm. Pygidium not differentiated, large, apex broadly rounded, with three pairs of lobes. Median lobes one-and-a-half times longer than wide, apically contiguous; inner margins straight, convergent; latero-apical margin curved, with fine indentations. Second pair of lobes shorter than the median lobes, linear, separated from the median lobes by more than a median lobe's width; third pair of lobes similar to the second, separated from the second by one-and-a-half times a median lobe's width. Basal scleroses absent. Paraphyses as a short pair in the first and second interlobal areas. Plates in the

Fig. 21.

Myrtophila pseudadnatae. Outline of Body. (× 180.)

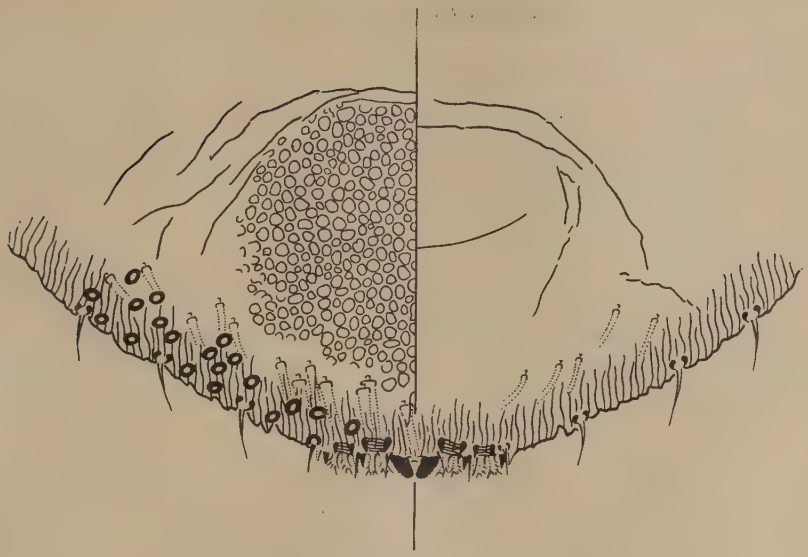

Fig. 22.

Myrtophila pseudadnatae. Enlargement of Pygidium. (× 350.)

first, second and third interlobal spaces; two plates in the first space, as long as the median lobes, apically branched; three plates in the second space, the first acicular, the other two similar to those in the first space; one conical simple plate in the third space. Spines adjacent to the median lobes shorter than the lobes, other spines longer. Dorsal ducts few, short, just exceeding the distance of the anal opening from the lobes in the medial region; ducts and duct heads wide in the median area and in the first and second duct furrows, becoming progressively narrower anteriorly; one large duct in the median area, two large ducts in the first furrow, one slightly smaller between the first and second furrows, one large and one smaller in the second furrow, two between the second and third furrows, four in the third furrow, then three intervening and six in the fourth furrow; a few ducts submarginally on other abdominal segments and metathorax. Perivulvar pores absent. Anal opening in an elongate inverted V a lobe's length or slightly more from the bases of the median lobes. Vulva wide. Thoracic tubercle absent. Pygidium dorsally with a reticulate sclerotization, ventrally with a stipple-like sclerotization. Anterior spiracles with three associated pores.

Notes.—This species closely resembles *M. adnatae* but differs in having three pairs of lobes and in the median lobes being convergent and apically contiguous.

Type Reg. No. T.5721 and paratypes Nos. T.5722 to T.5724 in the Queensland Museum.

NEOCLAVASPIS new genus.

Generic type.—Neoclavaspis duplex n.sp.

Characters.—Adult female membranous, with median pair of lobes only, these being broad and basally yoked; plates absent; paraphyses indistinct; ducts sparse and slender; anal opening small, paravulvar folds co-linear with the dense arms diverging from near the apex; lateral and median dorsal scars prominent, the median scars duplicated.

Notes.—The species assigned to this genus has some resemblance to some species in the genus *Clavaspis* and also to some in *Quadraspidiotus*. This genus, however, differs from *Clavaspis* in not having strongly developed paraphyses in the first and second interlobal areas, and from *Quadraspidiotus* in not having the second pair of lobes developed.

Neoclavaspis duplex n.sp.

(Figs. 23 and 24.)

Fig. 23.

Neoclavaspis duplex. Outline of Body. (× 70.)

Fig. 24.

Neoclavaspis duplex. Enlargement of Pygidium. (× 300.)

Locality and host.—Queensland: Texas, on *Eremophila mitchellii* Benth. Oct. 1954.

Habit.—Insects sparse on twigs. Scale of adult female circular, 1·6 mm. diameter, colour obscured by extraneous matter.

Recognition characters.—Adult female membranous, broadly pyriform to subcircular, length of slide specimen 1·35 mm., width 1·2 mm. Pygidium wide, apex obtuse, with median pair of lobes only. Lobes wider than long, yoked basally, separated by one-third of a lobe's width; inner margins curved; latero-apical margin strongly convergent to the rounded apices and with three small indentations. A thickening arising as a basal sclerosis from the central one-third of each lobe, longer than the lobes and the pair slightly divergent. Paraphyses as a faint short pair in the first interlobal area. Plates absent. Spines adjacent to the lobes shorter than the lobes, other spines longer than the lobes. Ducts sparse, very slender, heads small, in the median area longer than the distance from the lobes to the anal opening. Perivulvar pores absent

Anal opening round, twice the length of the lobes distant from the lobes; an anal groove extending posteriorly to between the bases of the lobes. Vulva three times the distance of the anal opening from the bases of the lobes. Lateral and median pygidial scars distinct; second pair of median pygidial scars also distinct, shorter than the first. Paravulvar folds distinct, almost straight, posteriorly convergent. Arms of the radiating pygidial thickenings distinct and more or less co-linear with the paravulvar folds.

Notes.—The basal scleroses merge into the thickened arms radiating from the pygidial apex.

Type Reg. No. T.5725 and paratypes Nos. T.5726 and T.5727 in the Queensland Museum.

Pseudotargionia asymmetrica n.sp.

(Figs. 25 and 26.)

Locality and host.—Queensland: Winton, on *Eucalyptus camaldulensis* Dehn., Apr. 1954.

Habit.—Insects single or in small colonies, individually subdermal in the leaf tissue, indicated by small oval surface pimples 0·75 mm. across. A few male scales present on the leaf surface, oval, dark fawn, pellicle dark.

Recognition characters.—Adult female subcircular, membranous, with a slight thoracic constriction; anterior portion dome-shaped, almost as large as the posterior portion, which is semicircular. Length of slide specimen 0.6 mm.,

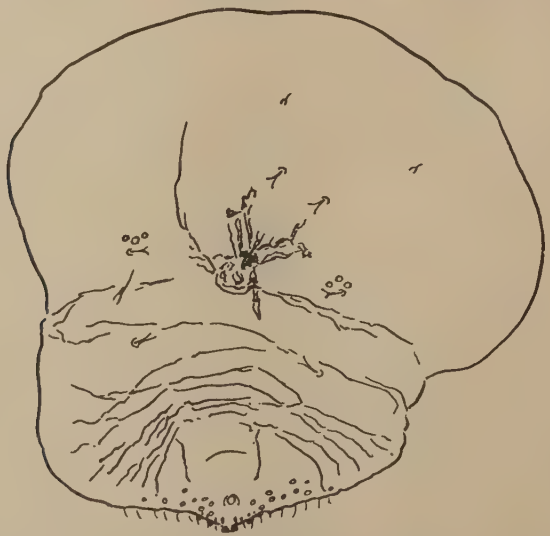

Fig. 25.

Pseudotargionia asymmetrica. Outline of Body. (× 120.)

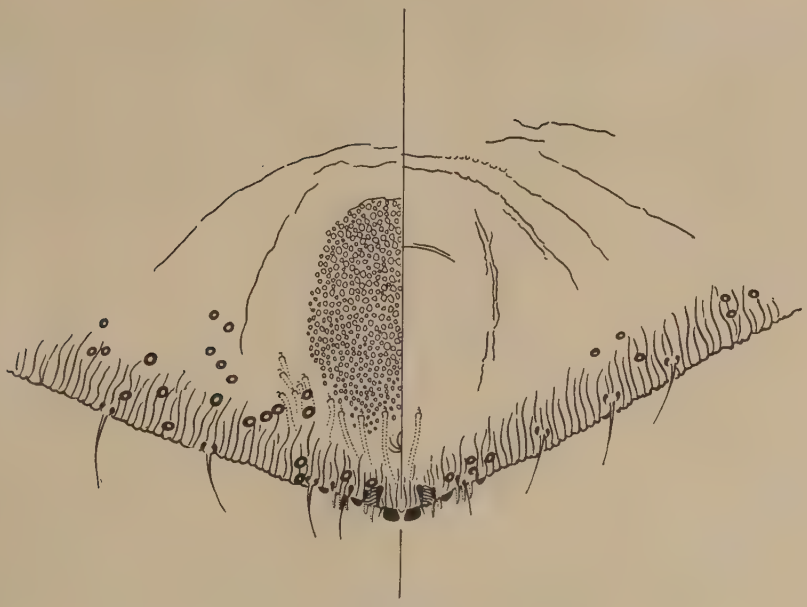

Fig. 26.

Pseudotargionia asymmetrica. Enlargement of Pygidium. (× 315.)

width 0·6 mm. Pygidium not differentiated, apex broadly obtuse with two, sometimes three, pairs of lobes. Median lobes slightly wider than long, narrow basally; inner margins slightly convergent, outer margins curved, apex truncate or broadly rounded; contiguous or almost so. Second pair of lobes much smaller, triangular, apex rounded, separated from the median lobes by slightly more than a median lobe's width. Third pair of lobes small triangular points, separated from the second lobes by one-and-a-half to two times a median lobe's width. Basal scleroses absent. Paraphyses uneven in the first interlobal area, more definite on the inner side, as long as the lobes; similar but smaller in the second interlobal area. Spines adjacent to the median lobes shorter than the lobes, other spines very much longer, some up to five times the length of the lobes. Plates present in the first and second interlobal spaces; two in the first space, slender, as long as the lobes; three in the second space, slender, longer than the median lobes. Dorsal ducts slender, longer in the first furrow than the distance from the lobes to the anal opening, segmental series not distinct; three or four ducts in the first furrow with orifices between the paraphyses; orifices of other furrows somewhat dispersed. Anal opening small, oval, two-and-a-half times the length of the median lobes from the base of the lobes. Vulva four times the distance of the anal opening from the lobes. Paravulvar folds distinct. A fine reticulate sclerotization dorsally on the pygidium. Anterior spiracles with two or three associated pores.

Notes.—The third pair of lobes may be very small or indistinct on one or both sides of the pygidium. Older specimens are asymmetrical in that one side of the abdomen may be enlarged. Pores associated with anterior spiracles may vary from one to four.

This species resembles *P. comata* (Maskell) in having very long hair-like spines but the body constriction is smaller and divides the body into parts of almost equal size. The asymmetrical shape and subdermal position in the host leaves are not shown by other species in the genus.

Type Reg. No. T.5728 and paratypes Nos. T.5729 and T.5730 in the Queensland Museum.

Pseudotargionia isaensis n.sp.

(Figs. 27 and 28.)

Locality and host.—Queensland: Mt. Isa, on *Amyema sanguinea* (F. Muell.) Danser, Jan. 1958 (H. J. Lavery).

Habit.—Insects mostly single on twigs. Female scale circular, 1·0 mm. diameter, light to dark fawn in colour, margin paler; second pellicle covered with light fawn secretion; first pellicle central, dark greenish brown.

Recognition characters.—Adult female subcircular with a deep thoracic constriction, anterior portion dome-shaped; posterior portion wider, semi-circular; length of slide specimen 0·7 mm., width 0·7 mm. Pygidium large,

Fig. 27.

Pseudotargionia isaensis. Outline of Body. (× 120.)

apex broadly obtuse, with three pairs of lobes. Median lobes as wide as long, more dense on basal angles, apically almost contiguous, lateral and apical margins curved. Second pair of lobes much smaller, triangular, separated from the median lobes by a second lobe's width. Third pair of lobes similar to the second pair but smaller, separated from the second by one-and-a-half

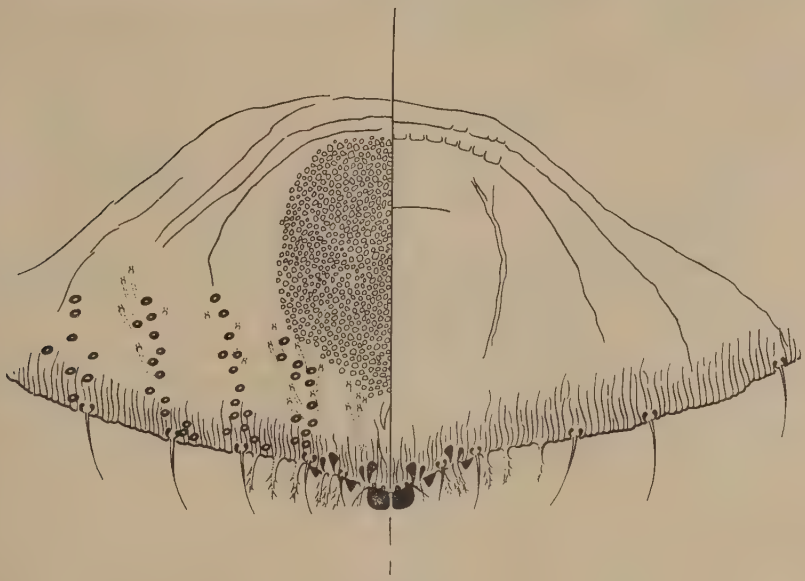

Fig. 28.

Pseudotargionia isaensis. Enlargement of Pygidium. (× 295.)

times a median lobe's width. Basal scleroses absent. Paraphyses as a pair in the first and second interlobal areas, short, more prominent on the posterior side of each area. Plates present in the first, second and third interlobal spaces, slender and apically branched; one in the first interlobal space, as long as the median lobes; three in the second space, elongate, branched, longer than the lobes; three in the third space, similar to those in the second space. Spines long and hair-like. Dorsal macroducts of moderate length, just exceeding the distance from the median lobes to the anal opening in the median area; orifices in segmental series, 4 ducts in the median interlobal area, 5 in the first duct furrow with orifices between the paraphyses, 11 or 12 in the series of the second furrow, 14 to 16 in the third furrow and 13 to 15 in the fourth furrow, with less on anterior segments. Perivulvar pores absent. Anal opening small, in an inverted V, two-and-a-half times the length of the median lobes from the bases of the lobes. Anterior spiracles with two associated pores. Dorsal pygidial area with a fine reticulate sclerotization. Derm of

mature females with heavy fingerprint thickening. Prepygidial segments with a fine palisade pattern or posterior margins. Position of lateral tubercle demarcated by an oval area within the fingerprint sclerotization.

Notes.—This species has some resemblance to *P. asymmetrica* but differs in having normal body symmetry, and plates in the third interlobal space as well as in the first and second spaces.

Type Reg. No. T.5731 and paratypes Nos. T.5732 and T.5733 in the Queensland Museum.

Remotaspidiotus albus n.sp.

(Figs. 29 and 30.)

Locality and host.—Queensland: Eulo, on *Santalum lanceolatum* R. Br., Oct. 1954 (L. S. Smith).

Habit.—Insects scattered on leaves. Scales white, convex, circular, 1·5 mm. diameter; second pellicle fawnish yellow with a white suffusion, first pellicle light olive green.

Recognition characters.—Adult female membranous, subcircular, length of slide specimen 0·6 mm., width 0·5 mm. Pygidium broad, median pair of lobes only. Lobes as wide as long, apically convergent and almost contiguous; inner and outer margins subparallel, inner concave, outer convex; apex truncated or concave. Basal scleroses as long as but narrower than the lobes.

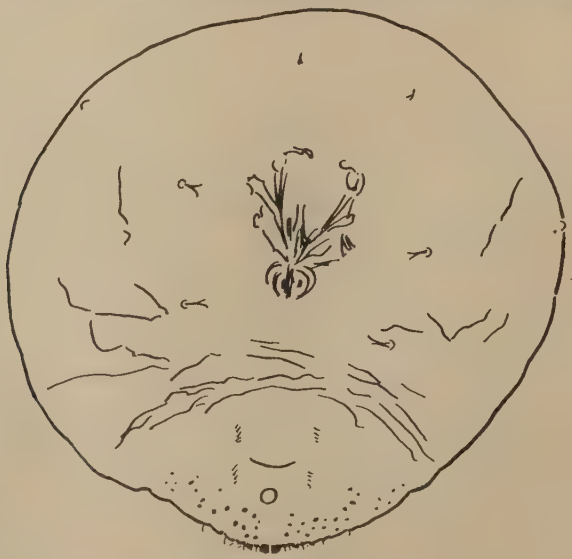

Fig. 29.

Remotaspidiotus albus. Outline of Body. (× 80.)

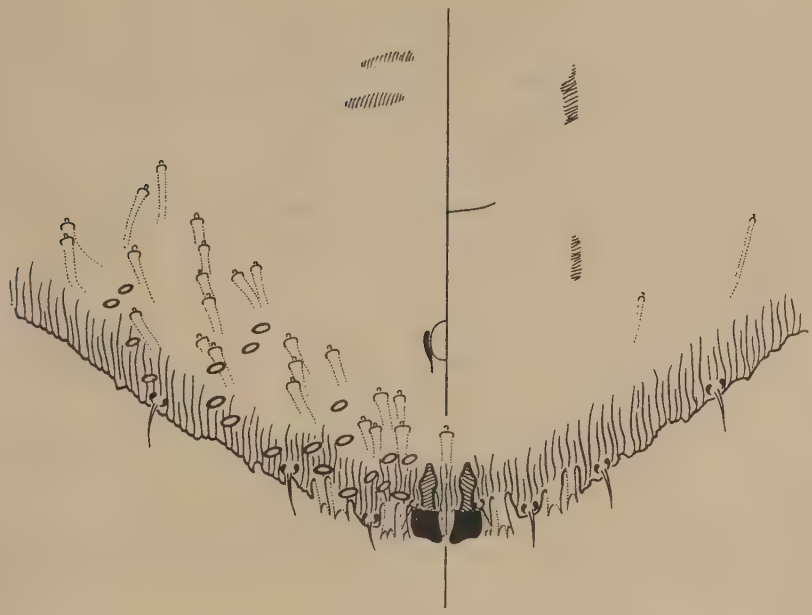

Fig. 30.

Remotaspidiotus albus. Enlargement of Pygidium. (× 395.)

Paraphyses absent. Plates in the median first and second interlobal spaces; two in the median space, as long as the lobes, slender and simple; two in the first interlobal space, as long as the lobes, mostly with two slender apical branches; two in the second interlobal space similar to those in the first space. Spines adjacent to the lobes shorter than the lobes, other spines slightly longer. Dorsal macroducts short, length half the distance from the lobes to the anal opening, in segmental series; one in the median interlobal area; three in the first furrow, two intervening between the first and second furrows; three in the second; one or two between the second and third with six in the third furrow; becoming smaller on the fourth and anterior abdominal segments. Perivulvar pores absent. Anal opening larger than a lobe, four times the length of a lobe from the bases of the lobes, and half the distance from the lobes to the vulva. Paravulvar folds not conspicuous, divided into widely separated short anterior and posterior portions. Median and lateral dorsal pygidial scars not conspicuous. Median dorsal pygidial scars in two pairs, anterior to the position of the vulva, not conspicuous. Spiracles small. A low broad dome-shaped marginal thoracic tubercle anterior to the anterior spiracles.

Notes.—The rims of dorsal duct orifices are slightly thickened. The ventral ducts are slender and inconspicuous, orifice rims are not thickened. The first and second interlobal spaces are in distinct depressions, making the

intervening marginal derm prominent but there are no lobes in these positions. The first plate in each of the first and second interlobal spaces may be fimbriate. This species resembles *R. coralinus* (Froggatt) but differs in having the paravulvar folds divided, the anal opening a greater distance from the lobes and the lobes more characteristically truncate.

Other material examined is from South Australia, on quandong, Nov. 1929 (J. Davidson), and New South Wales, Nyngan, on dogwood, June 1910.

Type Reg. No. T.5734 and paratypes Nos. T.5735 to T.5737 in the Queensland Museum.

Remotaspidiotus reconditus n.sp.

(Figs. 31 and 32.)

Locality and host.—Queensland: Marmor, on *Eremocitrus glauca* (Lindl.) Swingle, Oct. 1955.

Habit.—Insects under a species of *Septobasidium*. Scale of adult female circular, 1·3 mm. diameter, fawn or greyish white in colour; pellicles dark orange.

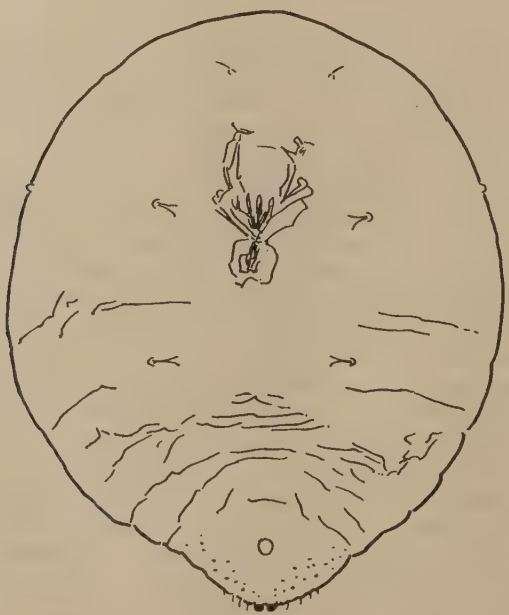

Fig. 31.

Remotaspidiotus reconditus. Outline of Body. (× 180.)

Fig. 32.

Remotaspidiotus reconditus. Enlargement of Pygidium. (× 400.)

Recognition characters.—Adult female membranous, broadly pyriform, length of slide specimen 1·0 mm., width 0·6 mm., Pygidium demarcated by longitudinal light fingerprint thickening, apex broadly rounded, median pair of lobes only. Lobes as wide as long, separated by less than one-quarter of a lobe's width; inner and outer margins almost parallel; inner margins slightly concave and slightly convergent; outer margins convex with a subapical indentation; apex rounded or truncated. Basal scleroses arising nearer the inner margin of the lobes, as long as or slightly shorter than the lobes, less than half the width of the lobes. Paraphyses absent. Plates in the first and second interlobal spaces; two plates in the first space, shorter than the lobes but in a deep dermal incision, linear, apices bifid; two plates in the second space, wider and shorter than those in the first space, bifid. Spines adjacent to the lobes shorter than the lobes, other pygidial spines longer than the lobes. Dorsal ducts short, slender, in the median region reaching for two-thirds of the distance from the lobes to the anal opening, segmental series not distinct; four or five orifices in the first duct furrow, about nine in the second furrow, others scattered anteriorly on abdominal segments. Anal opening oval, four times the length of the lobes distant from the lobes, two-thirds of the distance of the vulva from the lobes. Perivulvar pores absent. Lateral and median

pygidial scars absent or indistinct. Paravulvar folds divided, each portion short. A low dome-shaped process in the position of the lateral marginal thoracic tubercle.

Notes.—Sometimes the subapical indentation on the lobes is included in a concave or truncated apex typical of the genus. There are in some specimens indications of a pair of short simple plates in the median interlobal space but the lobes mostly are so close that these plates appear to be absent.

This species resembles *R. bossieae* (Maskell) but differs in having divided paravulvar folds, the lobes are closer and are not wider than long.

Type Reg. No. T.5738 and paratypes Nos. T.5739 to T.5741 in the Queensland Museum.

Remotaspidiotus squamosus n.sp.

(Figs. 33 and 34.)

Locality and host.—Queensland: Texas, on *Eremophila mitchellii* Benth., Oct. 1954.

Habit.—Insects sparse on leaves and twigs. Female scales whitish in colour, circular, 1·0 mm. diameter; pellicles yellow.

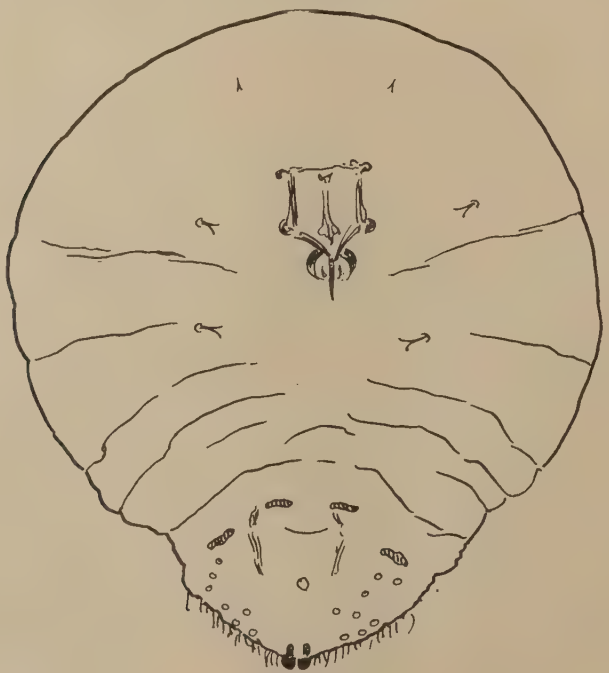

Fig. 33.

Remotaspidiotus squamosus. Outline of Body. (× 180.)

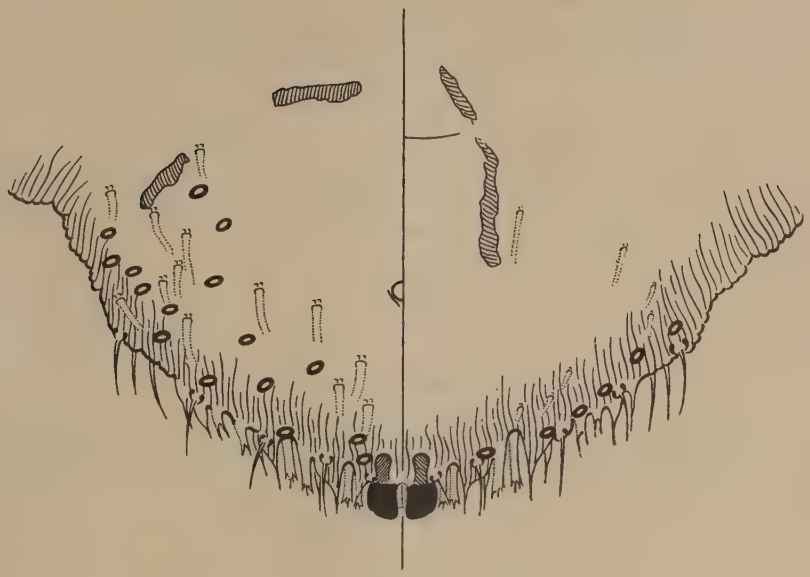

Fig. 34.

Remotaspidiotus squamosus. Enlargement of Pygidium. (× 450.)

Recognition characters.—Adult female subcircular to broadly pyriform, length of slide specimen 0·6 mm., width 0.45 mm. Pygidium broadly rounded with median pair of lobes only. Lobes slightly longer than wide, slightly narrowing basally on both margins, apically broadly truncated with a small latero-apical indentation, separated by one-quarter of a lobe's width. Basal scleroses arising centrally from the lobes, half as wide as and shorter than the lobes, apically broadly rounded. Paraphyses absent. Plates numerous; two in the median interlobal space, shorter than the lobes; three in the first interlobal space, as long as or longer than the lobes, the second in a derm incision. Four in the second interlobal space, longer than the lobes, the first and fourth simple, second and third apically branched, the third in a deep derm incision; four in the third interlobal space, slender but wide basally, the first and fourth simple, second and third bifid; three or four in the fourth interlobal space, slender and simple. Spines adjacent to the lobes as long as the lobes, other pygidial spines longer. Dorsal ducts sparse, length in the median area one-third to one-half the distance from the lobes to the anal opening; orifices normal, two in the first duct furrow, five or six well spaced in the second furrow, five or six in the third furrow. Ventral ducts with comparatively large orifices mostly near the pygidial margin, increasing in number on anterior segments with as many as 10 on the third abdominal segment. Anal

opening small, round, five times a lobe's length from the bases of the lobes. Vulva twice the distance of the anal opening from the lobes. Perivulvar pores absent. Paravulvar folds and lateral and median scars prominent.

Notes.—The prosoma is slightly sclerotized and of an asymmetrical shape in one specimen. A small dome-shaped thoracic tubercle may be evident.

This species varies in general appearance from others in the genus, especially in the number and shape of the plates, but the combination of other characters such as the lobes, basal scleroses and pygidial scars shows greatest affinity with the genus *Remotaspidiotus*.

Type Reg. No. T.5742 and paratype No. T.5743 in the Queensland Museum.

ACKNOWLEDGEMENTS.

Thanks are due to Mr. S. L. Allman, Chief Entomologist, New South Wales Department of Agriculture, and Dr. A. J. Nicholson, Chief, Division of Entomology, C.S.I.R.O., Canberra, for the loan of material. Mr. William Manley, Departmental Illustrator, made all the drawings.

STUDIES OF THE COCCOIDEA

9. NEW SPECIES OF *APIOMORPHA* FROM QUEENSLAND

By A. R. BRIMBLECOMBE, M.Sc., Senior Entomologist, Division of Plant Industry.

SUMMARY.

New species described in the genus Apiomorpha **are** A. amarooensis **and** A. longiloba; **both are from Queensland.**

Apiomorpha amarooensis n.sp.

(Figs. 1 and 2.)

Locality and host.—Queensland: "Amaroo," Millmerran, on *Eucalyptus pilligaensis* Maiden, Apr. 1955 (J. Macqueen).

Fig. 1.

Apiomorpha amarooensis. Adult Female. (× 15.)

Fig. 2.

Apiomorpha amarooensis. Female and Male Galls.

Habit.—Female galls on twigs, single or in clusters varying in number up to eight, semi-erect, green, sessile, cylindrically elongate-oval, uniformly longitudinally fluted, apical opening circular, length 10·0 to 15·0 mm., diameter 3·0 to 4·0 mm. Young galls similar but cylindrical.

Male galls on leaves, single or in groups, erect, green to reddish brown, mostly slightly curved, apically trumpet-shaped, length 4·0 to 5·0 mm., diameter 0·75 to 1·0 mm., apex 2·5 mm. in diameter.

Recognition characters.—Adult female narrowly turbinate, thoracic region widest, length of slide specimen 7·0 to 9·0 mm., width 3·0 to 3·5 mm., length of anterior portion subequal to total length of abdomen. Anterior portion membranous, clothed with fine hairs. Antennae short, four segmented, first segment widest, second a ring-segment, third and fourth segments of comparable length and width, fourth surmounted by a cluster of stout setae almost as long as the segment. Legs of similar shape, fore-legs half the size of the mid-legs and these half the size of the hind-legs, lightly to moderately sclerotized, coxa wider than long, femur longer than wide and as long as the coxa, tibia as long as the width of femur, coxa and femur of hind-legs with a noticeable mottled sclerotization. Abdomen much narrower than the anterior portion of the body, tapering posteriorly, segments 2 to 7 equal or subequal in length, moderately heavily clothed with acicular setae, more numerous and somewhat lanceolate in the posterior dorsal region on all segments and similarly ventrally on segments 6 and 7, setae longest on segment 6. Segment 5 with a transverse dorsal posterior row of six dagger-like spines, segment 6 with eight similar spines. Faint sclerotization on segments 1 and 2, more dense on segments 3 and 4 and heavy on segments 5 to 7. Terminal appendages on lobes twice or almost twice the length of segment 7, very heavily sclerotized, lanceolate, sharply pointed, slightly divergent apically, armed with dagger-like spines on the submedian region, two to five showing on lateral margin in slide specimen, one showing on internal margin one-quarter of distance from the tip of the appendage, a long hair-like seta placed similarly on lateral margin and reaching almost to the tip of the appendage.

Notes.—Antennal segments vary in size and proportional size. Some specimens have a mottled appearance on the mid-legs and a faint similar appearance on the fore-legs.

The circular apical opening, general shape and attachment of the gall show that this species has relationships with *A. attenuata* (Froggatt), *A. conica* (Froggatt) and *A. pedunculata* (Fuller), but the longitudinal fluting is distinctive. The large and lanceolate terminal lobes of the adult female are also distinctive characters.

Type Reg. No. T.5744 and paratype Nos. T.5745 to T.5747 in the Queensland Museum.

Apiomorpha longiloba n.sp.

(Figs. 3 and 4.)

Locality and host.—Queensland: Barakula, on *Eucalyptus crebra* F. Muell., Aug., 1939.

Habit.—Female gall single on a twig, green, semi-erect, sessile, body of gall narrowest basally, gradually enlarging apically, quadrate in cross-section, each angle flanged, the four flanges uniting above the apex of the gall body and continuing as a four-flanged extension which is as long as the body of the gall but gradually becoming smaller; apex of the gall body depressed and within the depression a central large nipple bearing the round apical orifice. Length of the body of the gall one-and-a-quarter inches, total length with flanged extension two-and-a-half inches.

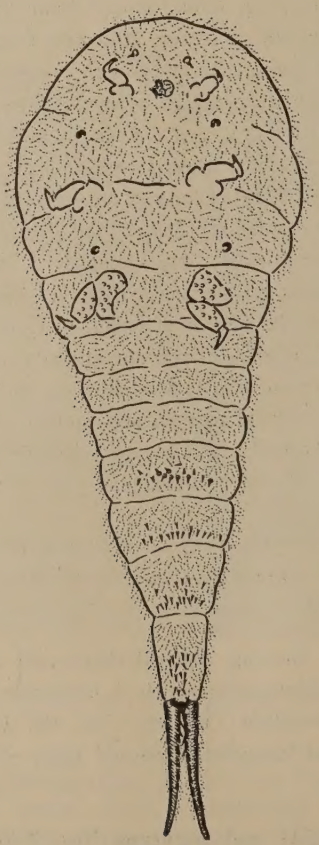

Fig. 3.

Apiomorpha longiloba. Adult Female. (× 12.)

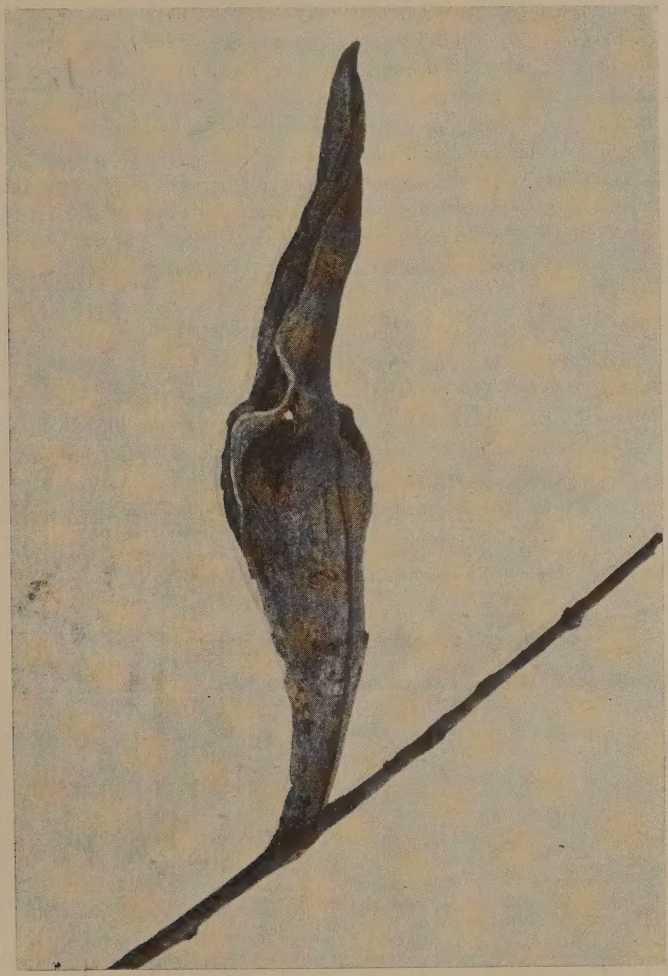

Fig. 4.
Apiomorpha longiloba. Female Gall.

Recognition characters.—Adult female narrowly turbinate; thoracic region widest; length of slide specimen 10·0 mm., width 3·5 mm. Body membranous, with numerous fine hairs. Antennae short, basal segment widest, segmentation indistinct, apical portion narrowly conical, apex rounded with four long and two short apical setae. Legs of similar shape; fore-legs half the size of the hind-legs, mid-legs of intermediate size; moderately sclerotized; coxa wide, wider than long; femur twice as long as wide; tibia small and narrow, half as long as femur; sclerotization of coxa and femur of hind-leg

mottled. Abdomen narrowing posteriorly, clothed with numerous fine hairs; segments 1 to 3 of comparable length, shortest; segments 4 and 5 barely longer, subequal in length; segment 6 longer still, segment 7 longest, longer than wide; segments 4 to 7 with bands of spines, transverse on segments 4 to 6, about 15 spines on segment 4 in one row; 15 spines on segment 5 in one row except five slightly displaced anterior to the row; 18 on segment 6, eight irregularly displaced anteriorly; 16 on segment 7 in an irregular central longitudinal band. Terminal appendages or lobes lancelate, one-and-a-half times as long as segment 7, clothed with numerous fine hairs, inner margins finely serrate; divergently curved, apically pointed. Anal opening surrounded by a sclerotized ridge.

Notes.—The lanceolate abdominal lobes resemble those of *A. amarooensis* and *A. urnalis* (Tepper) but the species differs from both of these in the number, shape and position of the spines on the abdominal segments and in the proportionate size of the legs. The gall of *A. urnalis* has an apical nipple but neither this species nor *A. amarooensis* has a quadrate cross-section. The gall of *A. helmsii* Fuller has a gall body shape and apical nipple resembling this species but differs in having five to seven lateral ribs and no flanged extension beyond the apex.

Type Reg. No. T.5748 in the Queensland Museum.

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